PROGRESSING SCIENCE

How fundamental science is having a profound impact on both society and industry
COMMENT

A new report suggests that too many companies are failing to close 'open doors' leaving them vulnerable to cyber attacks.

Cree to expand its silicon carbide capacity with the development of a 200mm fabrication facility.

Brighton Festival is partnering with the Digital Catapult to launch arts and cultural venues equipped with 5G.

Imec demonstrates a fully monolithic co-integration of half-bridge and drivers on a GaN IC.

Despite 5G it's unlikely that Wi-Fi will go away, so how do we enable a seamless transition between the two.

COVER

Fundamental science
Fundamental research is pushing the boundaries of science but also helping to transform society itself, as Neil Tyler discovers.

INTERVIEW

Precision medicine
AI and tech leader, Loubna Bouarfa, explains to Bethan Grylls why she is embracing diversity in technology for healthcare.

STORAGE TECHNOLOGY

SSDs start to crunch the numbers
Pushing computation into storage is one way server designers intend to stay ahead of demand, according to Chris Edwards.

TEST & SIMULATION

Engineering simulation
Simulation tools have such an important role to play in the development and testing of new rail technologies. By Neil Tyler.

POWER

Understanding power complexity
Current x86 hardware architectures are designed to provide optimal performance.

MISSION STATEMENT

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A new report looking at how companies are addressing the issue of cyber security makes for interesting, if slightly worrying, reading.

According to the report from 1E, a management and security company, businesses are ‘woefully unprepared’ for cyber breaches due to lack of IT security and operations basics and that despite 60 percent of businesses saying that they had experienced a serious security breach in the last two years.

A lot of the problems being caused are because of the digital transformation businesses are going through.

As a result, 80 per cent of respondents said that it was increasing the cyber risk to their businesses.

Interestingly, it was also found that the Dark Web was making it far easier for attackers to monetise stolen data.

Discussions around cybersecurity are covered regularly in the press – which isn’t surprising when you consider that the global spend on security is predicted to exceed $1 trillion through to 2021.

However, 1E’s research raises some important issues and suggests that while organisations may be spending vast sums of money on new and expensive tools, the real problem appears to be down to a lack of a cohesive relationship between IT security and IT operations.

The report found that fewer than a quarter of companies believe that their IT operations and IT security teams were working effectively together to secure the business, while 97 percent said their organisation would benefit from better collaboration between these teams.

Sumir Karayi, CEO at 1E warned that, “Businesses are losing control of their estates because of fundamental issues such as the widening gap between IT operations and IT security and deferred responsibility.”

There is also a lack of understanding of where the security focus should be.

Karayi observes that, “CIOs have the challenge of explaining the pivotal need for areas like patching, which can feel mundane. But without this hygiene, companies must constantly defend against new vulnerabilities or risk a major breach, which will lead to a software arms race.”

The answer appears quite mundane. IT operations and IT security teams must realise they while they have different objectives, they need to work together, agree their aims and create a shared toolset.

And when something goes wrong, don’t play the blame game!

Neil Tyler, Editor (neil.tyler@markallengroup.com)
We are now inviting entries for the 10th anniversary, British Engineering Excellence Awards to be held at the Landmark Hotel, London.

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Cree to invest $1bn in silicon carbide capacity

COMPANY PLANS ‘MEGA’ SILICON CARBIDE FABRICATION FACILITY. NEIL TYLER REPORTS

Cree has revealed plans to invest up to $1 billion in the expansion of its silicon carbide capacity with the development of a state-of-the-art, automated 200mm silicon carbide fabrication facility and a materials ‘mega factory’ at its campus headquarters in Durham, N.C.

The investment will be the company’s largest to date in fueling its Wolfspeed silicon carbide and GaN on silicon carbide business. Upon completion in 2024, the new facilities will help to substantially increase the company’s silicon carbide materials capability and wafer fabrication capacity, allowing wide bandgap semiconductor solutions that will be able to support the dramatic technology shifts underway within the automotive, communications infrastructure and industrial markets.

“We continue to see great interest from sectors looking to leverage the benefits of silicon carbide to drive innovation. However, the demand for silicon carbide has long surpassed the available supply. This is our largest-ever investment in production to dramatically increase this supply and help customers deliver transformative products and services to the marketplace,” said Gregg Lowe, CEO of Cree.

The plan delivers additional capacity for Cree’s Wolfspeed silicon carbide business with the build out of an existing structure as a 253,000 square-foot, 200mm power and RF wafer fabrication facility as an initial step to serve the projected market demand. The new North Fab is designed to be fully automotive qualified and will provide nearly 18 times more surface area for manufacturing than exists today, initially opening with the production of 150mm wafers. The company said it will convert its existing Durham fabrication and materials facility into a materials mega factory.

Latest version of JasperGold platform

Cadence Design Systems, has unveiled the third-generation of its JasperGold Formal Verification Platform, featuring machine learning technology and core formal technology enhancements.

The updates to the platform address the capacity and complexity challenges of advanced SoC designs with the aim of improving the speed of verification.

The platform represents the latest stage of ongoing proof-solver algorithm and orchestration improvements and incorporates Smart Proof Technology to improve verification throughput.

Machine learning is used to select and parameterize solvers to enable faster first-time proofs. Additionally, machine learning is used to optimise successive runs for regression testing, either on premises or in the cloud.

“We measured averages of 2X faster proof performance out of the box and 5X faster regression runs across our design testcases with the new smart JasperGold platform,” said Mirella Negro Marcigaglia, Digital Design Verification Manager at STMicroelectronics. “We are also seeing non-converged properties reduced by over 50%. Combined, these improvements significantly boost our verification productivity.”

The platform’s new formal coverage technologies let engineers perform IP signoff purely within the JasperGold platform.

Commenting Ziyad Hanna, corporate vice president, Fabric and Formal Solutions, System & Verification Group at Cadence said, “The smart JasperGold platform advances core formal technology, applying machine learning to achieve tangible performance and scalability benefits for our customers.”

The JasperGold Formal Verification Platform forms part of the Cadence Verification Suite, and offers coverage in the vManager Metric-Driven Signoff Platform, which combines JasperGold formal results with Xcelium simulation and Palladium emulation metrics.
The future of UK tech

In a Studio Graphene (SG) survey of UK tech firms, 79% said they are confident of their growth prospects in the next 12 months, despite the Government’s “awful” handling of Brexit.

SG found that just over half (53%) of early stage businesses in the country’s digital sectors believe Brexit will have a negative impact on their growth opportunities in the months ahead. In fact, 88% of those surveyed feel the Government’s handling of Brexit has been ‘awful’ (65%) or ‘poor’ (23%).

Looking ahead, 91% said they plan to hire more staff, 67% intend to expand into new overseas territories, and 66% will seek investment.

In terms of the challenges companies foresee, hiring the right talent was the most commonly cited issue, with 60% predicting this will be an obstacle to their future growth.

New IoT law proposed

Plans which are looking to make sure millions of connected household items are better protected from cyberattacks have been unveiled by the Digital Minister Margot James.

The options under review will include a mandatory new labelling scheme that would tell consumers how secure their products are, for example Smart TVs, toys and appliances. The move means that retailers will only be able to sell products with an Internet of Things (IoT) security label.

The security label will initially be launched as a voluntary scheme, helping consumers identify products that have basic security features and those that don’t.

National Cyber Security Centre (NCSC) Technical Director, Dr Ian Levy, said, “Serious security problems in consumer IoT devices, such as pre-set unchangeable passwords, continue to be discovered and it’s unacceptable that these are not being fixed by manufacturers.

“This innovative labelling scheme is good news for consumers, empowering them to make informed decisions about the technology they are bringing into their homes.”

5G ART

BRIGHTON DOME TO BECOME 5G TESTBED FOR CREATIVE INDUSTRIES.

BETHAN GRYLLS REPORTS

Brighton Dome & Brighton Festival is partnering with Digital Catapult to launch one of the UK’s first performance, arts and cultural venues equipped with 5G technology.

Jeremy Silver, CEO, Digital Catapult, said: “5G is expected to be rolled out across the UK later this year, but we’re still very much in the black and white television era of this technology. To be in with a chance of entering technicolour, we need to test the network’s capabilities and enable businesses and users to prepare for the opportunity it presents.”

Over the next year, the project will develop new ideas for integrating 5G technology into the venues, such as live streaming performances in high quality and real time. Audiences will be able to engage and interact with artists experimenting with new work enabled and delivered over 5G infrastructure.

The 5G network will initially be deployed in Brighton Dome’s Founder’s Room and Foyer, offering Brighton-based small businesses, community groups and artists the opportunity to test and develop new 5G-enabled applications.

The collaboration builds on the success of Digital Catapult’s existing 5G Brighton testbed delivered with Wired Sussex at the Fusebox, which is helping local businesses to develop 5G products and services. The testbed was funded by the Coast to Capital LEP with a £1.2 million Local Growth Fund contribution to enable the city to be at the forefront of innovation and offer businesses in the area access to new technology.

Tristan Sharps, Artistic Director of Brighton based performance company dreamthinkspeak, and associate artist of Brighton Dome & Brighton Festival, commented: “For artists, 5G has the potential to offer a new set of tools to do things we have always dreamt about or dream up new things we could never have imagined.”

Funds for 5G

mmWave System IP specialist Blu Wireless has raised £12.7m in a growth funding round led by existing investors Arm, Calculus Capital, Kendall and MGL, and including new investor Guinness Asset Management.

The investment will be used to scale the worldwide deployment of devices using the company’s HYDRA mmWave technology across a range of 5G applications.

Blu Wireless is working with tier-1 telecoms infrastructure providers and leading semiconductor companies in the US, Japan, the UK and mainland Europe as they look to deploy HYDRA based devices within applications demanding 5G levels of bandwidth and low latency connectivity.

Blu Wireless’s carrier-grade mmWave technology has been designed for the key markets of 5G telecoms infrastructure, Industry 4.0 and high-speed transportation.
Imec unveils single GaN IC

IMEC HAS BEEN ABLE TO INTEGRATE HALF-BRIDGE AND DRIVERS ON A SINGLE GaN IC. NEIL TYLER REPORTS

imec has been able to demonstrate a functional GaN IC that integrates a half-bridge and drivers on a single GaN IC.

Mounted on a buck-converter test board, the chip converts an input voltage of 48V to an output voltage of 1V, with a pulse width modulation signal of 1 MHz.

The achievement looks to leverage on imec’s GaN-on-SOI and GaN-on-QST technology platforms, reducing parasitic inductance and boosting commutation speed.

At present, GaN power electronics tend to be dominated by off-the-shelf discrete components. Half-bridges, common sub-circuits in power systems, are fabricated by separate discrete components, either in separate packages, or integrated in one package, especially for the higher voltage ranges. Realising half-bridges on chip by using GaN-on-Si technology, is challenging, especially at high voltages and is because half-bridges designed on GaN-on-Si technology are limited in performance by a back-gating effect that negatively affects the high-side switch of the half-bridge, and switching noise that disturbs the control circuits.

To unlock their potential, imec has monolithically co-integrated a half-bridge and drivers in one GaN-IC chip. Complemented by low voltage logic transistors, a suite of passive components for low-ohmic and high-ohmic resistors, and a MIM-capacitor, high-end integrated power systems can be realized on one single die.

The solution builds on imec’s GaN-on-SOI and GaN-on-QST technology platforms that allow for a galvanic isolation of the power devices, drivers and control logic, by the buried oxide and oxide-filled deep trench isolation. This isolation scheme not only eliminates the detrimental back-gating effect that negatively affects the high-side switch of the half-bridge, but also reduces the switching noise that disturbs the control circuits. With the design of a co-integrated level shifter for driving the high-side switch, a dead-time controller to avoid overlapping gate input waveforms, and an on-chip pulse-width modulation circuit, highly integrated buck and boost converters can be fabricated.

“Someone might think that by using SOI or QST wafers instead of Si wafers will result in more expensive technology. However, with GaN-on-Si several discrete devices need to be individually packaged (with advanced packages to take advance of the GaN fast switching performance) and connected to their drivers and other elements at the board or packaged level”, explained Denis Marcon, business development manager at imec.

“Instead, with imec’s GaN-IC technology, the full converter including drivers and analogue blocks etc. is on-chip, which can then be packaged with simple package technology (as the frequency sensitive components are already connected on-chip). This dramatically saves on the cost of the final power system.”

Avnet ASIC Solutions

Avnet Silica has announced the addition of Avnet ASIC Solutions to its line card of standard services, making its design skills and flexible business models directly accessible to customers across EMEA.

Covering the entire development cycle from specification to volume shipments, Avnet ASIC Solutions’ services include: logic design, verification, emulation, synthesis, chip layout, design for test, physical verification, package development, production test, hardware development, production, and logistics.

Avnet ASIC Solutions, based in Israel, has a long history spanning consumer, industrial, automotive, medical, and defence and aerospace markets and has expertise in areas such as AI, IoT, digital communications, and blockchain – encompassing the creation of new custom ICs or drop-in compatible replacements for obsolete parts.

“The company’s addition greatly strengthens the portfolio of ASIC services we can offer and enables us to connect with our customers,” said Frank Hansen Vice President Technical Resource and Marketing EMEA.

Avnet ASIC Solutions has developed a series of relationships with foundries among them, Samsung, Socionext, TSMC, GlobalFoundries, STMicroelectronics and X-FAB.

The service covers most processes including the most advanced 7nm EUV for digital, analogue or mixed-signal designs.

End of life pin compatible replacements for legacy standard-cell ASIC, gate-array ASIC, or FPGA technologies with 5V or 3.3V/5V core voltages are also available.

Innovation Hub for rail technology

The rolling stock operating company Porterbrook has unveiled a project to fast-track new ideas and accelerate service improvements.

Porterbrook, which supplies trains and carriages to major rail franchises, has converted a four-car class 319 train to create an Innovation Hub – it’s first public exhibition will be at Rail Live 2019 on June 19 to 20 in Long Marston, Warwickshire.

Among a number of companies asked to participate is FliteTrak which will be using the Hub to demonstrate its intelligent remote monitoring ViatorRail technology.

Commenting, Managing director Andrew Barnett said: “We’ll be installing ViatorRail on the Innovation Hub to show its capabilities in a ‘real’ train environment.

“It is already being used by a major rail franchise to track engine temperatures and performance but we’re looking forward to demonstrating all of its other applications too."

Porterbrook intends for the Innovation Hub to be used by SMEs which play an integral role in the UK rail industry’s supply chain, but face barriers to entry.

The Hub will focus on environmentally friendly manufacturing processes, improved passenger facilities, new uses of data and connectivity, and system monitoring.

FliteTrak will be among up to 25 businesses on the Innovation Hub at Rail Live.
At the end of March New Electronics looked at the impact 5G could have on Wi-Fi and concluded that, in all likelihood, the two technologies would continue to co-exist.

According to market research, smartphone users continue to spend around 70% of their time on Wi-Fi networks, so the real issue around these two technologies is how users will move from Wi-Fi onto cellular seamlessly avoiding ‘deadzones’ or suffering from time lags.

“Mobolize has developed on-device data management software that significantly improves the mobile data experience,” explains JP Brocket, the company’s Senior Director of Product Management.

Mobolize’s solution is deployed on millions of Android and iOS smartphones and it cuts across the entire mobile landscape from consumers and applications to operators.

“The big issue for consumers is connectivity – if you can’t provide that, operators will see increased churn, so eliminating this is crucial,” explains Brocket. “Operators want to avoid disruption and provide more differentiated services.”

The problem of connectivity will only get worse with the arrival of 5G and Wi-Fi 6. While more devices will enjoy greater levels of connectivity additional problems will be created, such as device security, power management and throughput latency.

“While 5G, for example, will enable the delivery of new services, these will be more demanding of the operators when it comes to connectivity,” says Brocket. “5G and Wi-Fi will need to be complimentary because consumers will want their devices to work, whatever path the device takes. It’s highly likely we’ll see congestion as services transition between Wi-Fi and cellular.

“The industry has to contend with two distinct radio and backhaul systems with differing governing bodies. These are duel path problems and, to date, little has been done to achieve greater alignment. Consumers and the application developer don’t care about the network – they just want their devices and services to work.”

This is where Mobolize plays a role, by making the device and service work regardless of how it is connected.

“For the consumer there are no ‘deadzones’ using our platform, for the application provider there is a smooth transition between cellular and Wi-Fi providing seamless connectivity.”

Currently most channel bonding solutions use a server or cloud platform, creating a single point of failure.

“Mobolize, by contrast, has developed an end-point solution. Our software can be deployed on IoT devices, handsets, and because it operates independent of the cloud or server, it avoids single points of failure.”

Some operators have embedded the solution into pre-loaded service offerings – high deployment and billing loyalty apps, for example - to ensure that consumers have access to new, data heavy services.

Mobolize also provides channel load balancing, avoiding ‘deadzones’ and enabling the onload of cellular more frequently.

“But it’s not just about signal strength,” explains Brocket. “We assess the entire data path, making decisions as to where that traffic is sent, ensuring that connectivity is maintained.”

The company’s platform provides both bonding and security; bonding ensures no connectivity issues, while the secure component is unique, according to Brocket.

“Security creates overhead, slows down connectivity and drains battery. Ours doesn’t secure what already is secure, we don’t secure what’s already been encrypted, for example. We secure unsecured content, encrypt and proxy it and then send it back to either a carrier or traffic end point. Your connection is always secure and through bonding there is no disruption to data.”

This bonding technology is relatively new, launched at the end of 2018.

“We are in a space that is massively competitive with 5G and Wi-Fi deployments, growing demand for always on connectivity, and network’s looking to differentiate their offering,” concludes Brocket.
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In March this year, hundreds of researchers and companies from across Europe, as well as university students and school children, came together to discuss the technologies being developed within the global Future Circular Collider (FCC) study.

The symposium - “Particle Colliders – Accelerating Innovation” - was co-hosted by the University of Liverpool and CERN, along with partners from the FCC and EuroCirCol projects, and looked to investigate the opportunities that next generation colliders could offer to industry, science and society.

Two months prior to this, CERN published its conceptual design report for the FCC, a potential successor to the Large Hadron Collider (LHC), which aims to be four times larger and seven times more powerful.

The fundamental science at the heart of this project not only pushes the boundaries of science but looks to benefit society, not only by generating knowledge but by creating unexpected and transformative applications.

Particle accelerators are at the heart of many of the most advanced research infrastructures and have led to the development of innovative technologies that have fundamentally changed peoples’ lives - whether through advances in medical imaging or the creation of the World Wide Web.

Particle accelerators are expected to have an even greater impact on science and society in the future and, according to Professor Carsten Welsch, Head of the University of Liverpool Physics Department, they should be seen as our generation’s equivalent of space exploration.

“They have the potential to change the world and improve our understanding of the fundamental building blocks and forces that make up our universe,” he argues.

“Developing the design concept for future research infrastructures is not just about the science they would enable; it also requires us to drive technological progress that will benefit our everyday lives.”

Strongening links between industry and academia, to pave the way for future collaborative projects, is critical for further advances in areas as diverse as cryogenics and superconducting magnets.

“Innovations derived from fundamental research have had many positive impacts beyond the laboratory,” according to Amy Bilton, Knowledge Transfer Officer, CERN.

“The aerospace industry has benefitted from CERN’s unique radiation testing facilities, for example, and several CubeSat systems were tested in CHARM (CERN’s high energy accelerator mixed-field facility) to compare ground and flight radiation data.”

One company attending the event in Liverpool, and an example of the synergies between fundamental research and the development of applications, is Oxford-based Adaptix, a partner in the pan-European research and training network OMA (Optimization of Medical Accelerators).

Working on laser-driven particle accelerators at UCLA (in Los Angeles), the company’s co-founder Dr Gil Travish saw the potential to use the emitter arrays he had developed in ‘gene-chips’, to help in the search for DNA unravelling and is now bringing a product to market.

According to Dr Travish, “It was encouraging to see how a concept born out of the pursuit of basic research could then be adapted to a very applied field.”

Conceptual design report
CERN’s conceptual design report for the FCC said that its objective would be to find new particles and offer a better understanding of the rules that ‘govern the universe’.

A particle accelerator uses electromagnetic fields to propel charged particles to very high speeds and energies and contain them within controlled beams.

The LHC is the world’s most powerful accelerator and can accelerate two beams of protons to an energy of 6.5 TeV and cause them to collide head-on, creating centre-of-mass energies of 14 TeV.

To achieve higher energies a longer tunnel is needed and while the LHC
runs to 27km, its successor will have a circumference of 80-100km, offering a centre-of-mass energy of the order of 100 TeV.

Crucially, the FCC is not just about progressing science but providing a well-controlled environment, a test-bed, to enable the development of technologies under conditions that extend well beyond conventional product requirements.

Industry partners will have access to an extensive academic community, in fact many of the companies that have benefited to date from involvement with the LHC have been SMEs. Through a number of successful collaborations, these small businesses have brought technologies to maturity, creating improved products and generating new markets.

Among the examples of technologies that have come out of work conducted at LHC are chip development in mobile devices, 3D scanners, 3D coloured X-rays, radiation monitoring in adverse environments, robotics, data communications and cryogenics.

The impact of the work carried out has been profound. In fact, 1400 firms in 30 countries have collaborated at the LHC and 25 companies are now involved in the first stage of the FCC.

Ross Robotics developed a robotic modular platform that can be re-configured to perform a variety of different tasks using a broad range of sensors and tools.

The platform was tested and used in CERN and was able to show that it could cope with very hostile conditions, from strong magnetic fields to transient radiation levels.

Another company, Medipix, developed a spectral imaging chip for a medical scanner derived from technology used by particle physicists at CERN, and which provides 3D colour x-rays to help consultants spot and then treat diseases without the need for surgery.

“Medipix’s technology is also being applied in the field of art restoration and is used for monitoring radiation levels in the International Space Station,” says Bilton.

Beyond these specific examples, though, a large-scale accelerator controlled and monitored by thousands of sensors and actuators actually provides a suitable test-bed for the technologies that are supporting Industry 4.0.

The smart factory requires the support of a cyber-physical system (CPS) that can act largely autonomously, continuously interacting with its environment and controlled by efficient embedded software.

But beyond that, some of the applications for CPSs also include consumer electronics, traffic control and critical infrastructure control.

**FCC collaboration**

According to Professor Welsch, to be able to reach the higher energy levels required by the FCC, high-energy electric fields will be needed to speed up the particles.

“The particles would need to be constrained to form beams that will bend in a circular trajectory,” he explains. “This would be achieved through the use of superconducting magnets, cooled to very low temperatures using large-scale cryogenic systems. Current magnetic fields in the LHC reach 8 Tesla; the new magnets will need to reach up to 16 Tesla.”

The knowledge as how to build these high-field magnets does not yet exist, so forms part of the FCC study.

“It is anticipated that the challenges associated with the FCC will drive innovation in areas such as precision mechanics, surface treatment, superconductivity and novel materials.

“Modelling and testing in extreme environments have wider applications, and advances in our understanding of the universe will come from measuring the physical phenomena with higher precision and comparing this to theoretical predictions,” explains Prof. Welsch.

The most advanced detector systems currently available are complex assemblies designed to record 4-dimensional data from a continuous stream of collisions, forty million times a second.

The FCC will require different approaches to achieve the ideal detector – one that offers infinite precision with zero mass.

“By aiming at this seemingly impossible goal the advances in technology will have spinoff benefits for less exacting applications,” says Prof. Welsch. “Improved techniques for particle detection, beam optimisation and monitoring have much wider applications.”

Advances in finite-element modelling and computational fluid dynamics are enabling the generation and acceleration of particles to be investigated in detail, but because the particle sources are complex and exhibit numerous emergent behaviours these cannot be predicted by simulation alone.

“Therefore, development rigs that replicate the actual environment and are equipped with diagnostics are essential,” says the professor.

To accelerate particles, the accelerators have to be fitted with metallic chambers containing an
electromagnetic field known as radiofrequency (RF) cavities. Charged particles injected into this field receive an electrical impulse that accelerates them.

“There are currently two main technologies: bulk niobium (Nb), which is widely used; and thin superconducting film coated cavities, which are only available in large laboratories,” explains Prof Welsch.

“Coated cavities are the subject of research and have huge potential for improving the efficiency and lowering the cost of accelerators.

“The LHC uses sputtered Nb on a copper cavity, technology which has been transferred to industry and now offers an alternative to bulk Nb and superfluid He cooling for applications that require low frequencies and 4.5K operation.

“As the RF current only penetrates a layer of a few hundred nanometres, films offer the potential to decouple the functions of the superconducting surface from the substrate.

“This creates the opportunity to large scale manufacture cavities in high thermal conductivity materials coated in a thin film of superconducting film. This would require developments in surface finishing and techniques for depositing high quality films on complex surfaces.”

**Superconducting magnets**

Before reaching the LHC particles pass through a series of smaller accelerators, and as they reach the maximum speed each accelerator can achieve, they are shot into the next. Without other forces involved the momentum of the particle would carry them in a straight line so 50 types of magnet are used to send them along complex paths without losing speed.

“Improving the efficiency of magnets through advances in mechanical design, electrical insulation, and quench protection would ease the demands on cryogenic systems, leading to increased stability and lower cost,” according to Prof Welsch. “Currently an increase in a magnetic field by a factor of 2 to 3 can significantly reduce the performance of ion sources and accelerators for the production of radionuclides and ion therapy.

“Producing reliable field strengths and qualities beyond 10 Tesla creates the opportunity for affordable and compact Nuclear Magnetic Resonance (NMR) analysis.”

NMR spectrometry is used to determine the structure of organic molecules, crystals and non-crystalline materials and in medical imaging techniques. The magnets in the LHC are made with coils of a superconducting material called Niobium-titanium (NbTi), but this material can’t support the high magnetic fields needed for the FCC, so new superconductors are being investigated.

The FCC aims to achieve a sustained field of up to 1.6 Tesla based on Nb3Sn LTS conductors operating at temperatures higher than superfluid Helium. However, this material is very brittle, making the production of coils with it difficult, so new processing techniques are also being investigated.

Particle accelerators operating at the high energy frontier result in costly electricity bills and large heat rejection. To improve efficiencies, the relationship between beam parameters and performance needs to be determined and extrapolated to define efficiency estimators – distinguishing intrinsic factors resulting from beam physics to those that depend on accelerator technology and infrastructure.

“This can underpin strategies to improve efficiencies that can be implemented through technology developments and improved energy management processes,” explains the professor. “The collider tunnel contains two adjacent parallel beamlines, which travel in opposite directions around the ring. The beams intersect at four points around the ring, which is where the particle collisions take place.

**Novel materials**

The investigation of novel materials, their behaviour and large-scale industrial applicability are essential for the beam-screen and beam-pipe system of the FCC.

“An example of this is Non Evaporable Getter (NEG) materials, which may lead to a successful transfer of fundamentally new technology to the market such as highly efficient solar panels; amorphous carbon with potential applications for powering systems at high frequencies and on-board radiofrequency systems for satellites; and molybdenum-carbide-graphite composites for use in aircraft design.”

The research and investment required to develop the FCC will also help to stimulate the development of embedded and real-time computing devices and improved tools for data management and storage.

By addressing the issues of reliability, availability, maintenance, support and safety of CPSs within the FCC, researchers will have the tools to then build a more reliable and energy efficient infrastructure.

The impact will also extend to civil engineering. The idea of tunnelling under the Alps to house the FCC is extremely ambitious. That to will require advances in tunnelling technologies to develop novel methods for online material analysis and separation to enable recovery and re-use of excavation materials and will involve material scientists, geologists and chemists.

The FCC certainly offers extraordinary opportunities for industry in terms of a better understanding of fundamental science, but also in pushing the limits of technology further and providing exceptional training for a new generation of technologists as they look to deliver new applications and devices.

“**Innovations derived from fundamental research have had many positive impacts beyond the laboratory.”**

Amy Bilton
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There is a diversity crisis in the AI sector. That’s according to a recent report from the AI Now Institute, a New York University research centre. Large-scale AI systems are said to be almost wholly developed by a small and elite set of university laboratories which are dominated by white, wealthy males.

As a female, Dutch, Moroccan, CEO of an AI data analytics company, Loubna Bouarfa knows she is a minority – or at least, perceived as one.

However, over time she has come to look at minorities a little differently than the rest; and this has been the inspiration for her healthcare-focused company, OKRA Technologies.

“For me, being a minority is not something that is an anomaly anymore,” she said. “When I was younger, perhaps then it felt like a bigger deal – but now, I don’t feel like the odd one out. I don’t feel different to, for example, a man in technology.”

She compares minorities to outliers – an observation point in a dataset which is significantly different to the overall result. In society we try to conform people to averages, she told NE, ignoring any differences – outliers – one may have.

“OKRA doesn’t believe in outliers,” she clarifies. “We have a highly diverse team because we need to design for everyone and that requires diversity. There are no outliers in the company because everyone is an outlier, everyone is special.”

Bouarfa has applied this principle to her work at OKRA, explaining that the company looks at AI and health data differently.

“There is no one size fits all,” she says, “but that is exactly the approach that the healthcare system takes. One medicine that is fit for all.

“The current framework for clinical drug trials are very strict,” she adds. “The data that is used to validate a drug is based on the average outcome.” She gives an example, “Let’s say you have diabetes, you may be excluded from a drug study because you’ll bias the results. But in my opinion, that’s not ok. When a drug is launched, it needs to be suitable for everyone to use.”

In other words, a drug may be intended to fit the majority, but is actually fit for a small portion of people because of the way in which it is tested and proven. Bouarfa intends to change this framework so that treatment can be validated on a much wider scale, bringing diversity to the data.

Through AI and partnerships with Life Science companies, Bouarfa explains that OKRA Technologies aims to make medical treatment more tailored. “I believe AI provides us with a framework to predict what the best treatment would be for each patient and what the likelihood is they’ll respond. The goal is to embrace everyone and all of their characteristics.”

Bouarfa says a career in technology was always the plan, but her ‘outlier’ philosophy can be traced back to her PhD days. “I designed an AI system for surgery to predict risk and error in the operation room and suddenly I realised, I could do more. AI could have a much wider impact than in just research and publication. I wanted to make a difference, so I decided to move to industry and establish my own company.

“I knew that if I didn’t start my own company, I wouldn’t be able to achieve what I wanted to,” she admits.

She explains that inciting change has always been a key driver for her. “Those who can make a difference whilst being humble enough to embrace uncertainty and take every day with optimism are the people I am inspired by most.

“I find uncertainty fascinating,” she adds. “I’ve always loved science and technology, but I became sceptical of how deterministic they both are – describing ‘the facts’. When I learnt about AI, I saw a technology that finally embraced human uncertainty. Like humans do, it looks at the past and predicts probable outcomes in the future. It reflects the human ability to learn and adapt based on past experiences. As we become able to track and predict the outcome of treatments for each patient, we can move from a volume-based healthcare system (meaning the more treatment and pills, the better) to a more outcome-based system, where the final result is our key measurement.”

To enable this outcome-based world she refers to, OKRA has developed a platform which integrates data from various sources, including its pharmaceutical clients and open source materials like demographic and environmental data, into one place. It then organises the data into what Bouarfa calls a “holistic view” about the disease, patient and even the country.

“Once we build that view, we train an AI algorithm to predict outcomes such as, how likely the patient will respond to a certain treatment and what other treatments are available. This is often called precision medicine.”

She continues, “Our clients can ask the system questions in a natural language – typing queries like ‘which clinical commissions group doctors are prescribing this treatment?’ into the platform.”
Machine learning expert, Loubna Bouarfa, CEO of OKRA, has a wealth of experience in implementing and commercialising AI systems for regulated environments. She is involved with the European Commission as a high-level expert on AI, where she helps to develop and support policies for effective development and production of AI systems.

‘Trust’ was also a key aspect of the technology, Bouarfa tells NE. “Our AI won’t just suggest treatments, but it will give reasons as to why it has suggested them. That is very important – if you have a system which just tells you to do something, you probably won’t listen. But if you have a system that suggests an action and why you should follow it, that enables trust.”

When designing the algorithm, Bouarfa explains that a lot of effort went into not just designing a system which could collate different forms of data into a single place, but also a system which didn’t hold bias. Not just in terms of race, sexuality and gender, but also in terms of the disease. “We have created an AI system which does not prejudice a person with multiple health issues,” she confirms.

As for the future, Bouarfa says the intention is to further diversify and tailor the health system. “My dream is to develop a proactive system that flags people’s risk of disease before the symptoms occur. A future where we don’t have to wait to get sick to get treated – and the treatment is right.”

She continues, “We’re helping a handful of European Life Science companies with decision-making right now, but I want to expand this, so that we’re not just helping single companies, but instead empowering a country by streamlining all their health data into one AI platform.”

Although it’s evident that both the AI and healthcare sectors are lacking diversity, perhaps industry can take a step back and learn from Bouarfa’s progressive approach.

Loubna Bouarfa

Machine learning expert, Loubna Bouarfa, CEO of OKRA, has a wealth of experience in implementing and commercialising AI systems for regulated environments. She is involved with the European Commission as a high-level expert on AI, where she helps to develop and support policies for effective development and production of AI systems.
Pushing computation into storage is one way server designers intend to stay ahead of demand.

By Chris Edwards

Addressing a group of data-centre operators and suppliers during his keynote at March’s summit organised by the Open Compute Project (OCP), Microsoft Azure’s hardware infrastructure general manager Kushagra Vaid pointed to statistics from IDC that claimed worldwide storage demand would surge to some 175 zettabytes by 2025 and how this would easily outstrip available capacity.

Vaid’s proposal to help deal with it was better compression. Microsoft Azure developed an algorithm that can pack the kinds of log and sensor data that cloud servers are expected to handle by factors of 90 per cent or more. To try to make it a standard, the company is providing free implementations that include a hardware design in RTL form that could go into storage controllers and not just be run as software by general-purpose processors.

The move to create RTL for a compression algorithm is just one example of the way in which users see storage hardware as becoming smarter and taking an active role in processing data on behalf of conventional processor blades.

Space utilisation is just one of the driving factors, said Shahar Noy, senior director product marketing at Marvell in a panel session at the OCP Summit.

He described the situation he saw at one installation where the operator was forced to leave gaps in server racks because there was insufficient power to run a full collection of blades. Distributing compute to nodes that have lower power demands, such as storage racks, would make it possible to squeeze more compute capacity into the same volume.

A further factor driving this change is the energy arithmetic of computation. Experiments have shown that almost all the power used to process data goes on moving that data around. The actual computation is a tiny fraction of the total. Another factor is latency and the number of hops it takes to get data from a drive into a processor.

Thad Omura, vice president of business development at ScaleFlux, says: “You can’t go through all the data if everything has to go up into the processor complex.”

It is possible to devolve processing to storage controllers that manage rotating disk drives, but the results can be disappointing. With traditional disk drives, the main factor in latency is the seek time. And for bandwidth, the limit is how fast the disk spins and the bit density, which limits the acceleration a smart storage controller can provide. But with solid-state devices, the internal bandwidth of a single drive can be enormous.

High-speed in-memory

Some memory manufacturers have proposed moving some of the processing into the memory arrays themselves to take advantage of that bandwidth. Micron’s Automata provided an example of what is possible with its Automata DRAM. Unveiled in late 2013, the use of processing engines distributed throughout the memory array made it possible to perform trillions of comparisons a second in search applications.

However, it suffered from a programming model that was very different to conventional techniques and Micron discontinued development after several years. The demand for high-speed in-memory search remains, however. The focus has simply shifted to the technique of attaching accelerators and processors to multiple banks of persistent memory.

“The big application today is data analytics are an important driver for computational storage beyond database searches: AI is the huge monster right, as well as image processing and image recognition.”

Steve Bates
database acceleration. There is a desire to be able to analyse data at lowest possible latency,” Omura claims. “But the market is just getting going now.”

Computational-storage vendors point to genomics as one area where tuned acceleration can work for their highly specific databases. A key application in genomics and medical research is the Basic Local Alignment Search Tool (BLAST). The algorithm is, at its heart, a string search with statistical enhancements to find similar sequences of DNA within genomes. Tests by computational-storage specialist NGD Systems demonstrated a near linear speedup across an array of storage processors as new nodes are added on top of host processors.

Steve Bates, CTO of Eideticom, points to data analytics as being an important driver for computational storage beyond database searches: “AI is the huge monster right, as well as image processing and image recognition.”

The problem that faces the nascent computational-storage industry is finding a way to make it possible for users to get their computational-storage systems to handle a variety of applications and to migrate software from one cloud server to another.

“We can align on certain APIs and, hopefully, products will conform to that same API,” Bates says. “The end consumer can worry more about whether your device is faster than another option, not whether they’ve got to develop a driver for your device.”

Although a common API looks plausible, there are major complications involved with the push of computation away from the main processor to storage coprocessors. The range of applications is diverse. A single drive cannot perform more than the simplest queries as it probably will not have all the data needed sitting on it.

Lower-level commands will need to be generated and sent to the drives in parallel used to pre-process data ready to be assembled in the larger query that the server processor itself has to run.

In between may be algorithms that perform low-level inferencing on incoming data to provide more complex machine-learning systems with access to higher-level tags rather than forcing all the data through the main server processors. Hardware implementations will vary widely.

“Some of us are going down the route of fixed function; others with processors in the drive. There are different models being tackled,” Omura says.

The range of hardware design extends from fixed-function accelerators that might, for example, be used to speed up SQL or BLAST queries, through the FPGAs employed by Samsung in its foray into computational storage through to software-programmable processors. Handling that range of options could be a problem for both hardware vendors and cloud-software developers. To try to work out what is needed, the Storage Networking Industry Association (SNIA) formed a working group last year and is now trying to canvas opinions from the software world into how a standard protocol might be expected to work. It is still early days with no clear guide as to what shape the protocol would take.

Protocol design will also need to take into account security. Operators want to be able encrypt data on their drives to minimise the damage caused by hacks. If the server encrypts the data before it hits the drive, there is no practical way for the storage processor to analyse it.

One future possibility lies in functional encryption, which lets software process data without first decrypting. As yet there is no general-purpose algorithm that makes it practical. The short-term answer is to let the drive store the decryption key.

“We need distributed key management. Whoever has the root of trust has to know it can trust the [storage]. These are problems that are solvable but they need to be tackled,” Bates says.

The interest in pushing computation into storage seems to be there. NGD’s vice president of marketing Scott Shadley said at the OCP Summit: “At this point we’ve become the fastest growing technical working group in SNIA.”

The open question is how quickly the SNIA can develop a workable standard.

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**Statistics from IDC claim that worldwide storage demand would surge to some 175 zettabytes by 2025 and this would easily outstrip available capacity.”**

Kushagra Vaid

Below: A graph that demonstrates the acceleration of BLAST, according to NGD Systems
Why simulation tools have such an important role to play in the development and testing of rail technologies.

By Neil Tyler

The demands for safer rail vehicles that are capable of higher speeds and carrying greater loads means that when it comes to the design, maintenance and modification of vehicles and the rail network itself, the challenges associated with these vastly complex systems can be immense.

The problems that have come to light with the construction of Crossrail in London have highlighted the enormity and complexity associated with these types of projects, not only in developing new trains and stations, but with rolling out new signalling systems, supporting software integration, control systems and then getting them to work together seamlessly.

Simulation tools are being used extensively to test all manner of systems across the Elizabeth Line. For example, the ventilation system has been designed to address various safety and compliance purposes in order to meet normal operations, maintenance and emergency situations.

Testing has been critical to this and a dedicated testing tunnel ventilation control system test suite has been used to mimic live operations.

Beyond this particular project, however, the rail industry also has to contend with much broader trends such as autonomous solutions and electrification.

When it comes to autonomous systems engineering, the focus tends to be on adapting rolling stock that were originally designed for human operators.

As for electrification, these systems tend to be lighter and easier to control than more traditional mechanical systems.

The growing use of electrification often requires a complete re-design of power systems and the need to replace legacy systems too, and that requires engineers to redesign systems safely, quickly and to budget.

ANSYS develops and markets software that can be used to simulate engineering problems.

The company’s SCADE and medini solutions are used for reliable and standards-compliant development, verification and automatic code generation of safety-critical systems and software applications across industry sectors, including the railways.

These solutions help to create models of structures, electronics and components to emulate, for example, their strength, elasticity, EMI and temperature. The company’s software is used to show whether a product will function in the real world while meeting different specifications and addressing various industry standards.

Crucially, all this can be achieved without the need and expense of building a functioning prototype.

According to Günther Siegel, VP Engineering at ANSYS, “Electrification, as well as growing autonomy, are driving the need for more safety critical solutions and, irrespective of sector, companies are faced with the same set of challenges.”

Both testing and validation, using simulation, are critical and the tools industry is investing heavily in creating more innovative simulation platforms.

“By using simulation software engineers can ensure that all electrical, mechanical and software control systems can interact safely and optimally, especially early on in product development cycles and without the need of having to invest in a physical prototype,” Siegel explains.

Simulation can help to solve a broad range of multi-physics and multifunctional performance issues quickly, which is becoming increasingly important as designers have to meet more aggressive development cycles.

For example, ANSYS has a model-based embedded software development and simulation environment with an automatic built-in code generator that helps to accelerate embedded software development projects.

“Our SCADE solution enables system and software engineers to graphically design, verify and generate critical systems and applications with high dependency requirements,” says Siegel. “They are interoperable
and easily integrated and have been certified to EN50128 up to SIL3/4 when it comes to rail transportation."

Intended for model based systems engineering, embedded control software development, virtual systems prototyping and functional safety analysis, SCADE can significantly speed up the design process, “by as much as 50 percent, on average, while aligning the design process to safety standard objectives which is critical when it comes to the rail industry,” suggests Siegel.

Focus on rail
While the issue of autonomy might not seem obvious, in relation to the rail industry, the use of autonomous systems is becoming increasingly important as the industry looks to determine accurately where trains are on a network, especially when they need to stop accurately at stations deploying platform screen doors, for example.

The cost of stopping a train automatically can be expensive, it requires continuous calibration as each train will need a different braking process – the number of carriages will vary, as will weight and the subsequent wear on the wheels.

A Spanish company, Autodrive Solutions, has developed a radar positioning system (RPS) that deploys clusters of plastic bars along railway tracks. The different sized bars represent a digital ‘0’ or ‘1’ which are then read by an RPS unit attached to a train to provide an accurate measurement of speed, which is then used to apply a customised breaking process.

To avoid imperfect code causing product failures, the company used SCADE to graphically design, verify and automatically generate applications and as a result was able to save 80 per cent in development time to get the product to market.

Simply by focusing on the model and letting SCADE develop certifiable software to control the hardware that they had developed, if a problem was found during testing all that was needed was to change the model.

SCADE was able to take the model then generate the code with a certified KCG compiler to provide the necessary traceability and documentation needed by the various certification authorities.

Once certified companies can then sell their technology to the wider market.

Currently, ANSYS is helping Poland’s Rail Mil to speed up the development of their embedded software to aid them in developing a fully CBTC class automatic train control system for the Polish Railway transportation sector.

The system will be the first system with such functionality put into operation in Poland. One of the main goals is to achieve the shortening of train headway with no regression for the safety level of the overall system, which is especially embedded in agglomeration zones i.e. where there is a lot of traffic on the network.

This communication-based train control system is intended to increase railway system capacity while maintaining existing safety levels.

“As industries continue to be impacted by the advancements in technology, organisations must strive to keep up with these changes and use new technologies to deliver better services.

“Of course, one of the main technological drivers in transport is autonomy, but this isn’t new. In the rail industry, autonomous trains are already being used across the world. Instead, the industry needs to focus on intelligent software,” explained Slawomir Jasinski, CEO Rail-Mil Computers.

“We are currently developing what will be the first communication-based train control system of its type in Poland and the support of ANSYS has been critical in supporting this business initiative.

“Compliance is a key challenge for the industry. Regulations require rail companies to implement comprehensive safety measures to ensure rail travel is safe.

“As we develop onboard systems for trains, the intelligent solutions we use have to be reliable and safe, as any issue could lead to serious consequences. We used SCADE to speed up embedded software development and ensure that we were compliant with EU regulations,” explained Jasinski.

Safety is critical but beyond testing Siegel makes the point that the user also needs to be kept ‘in-the-loop’.

“When you are addressing new technology, while testing is crucial, you need to bring innovation to the user and ensure that they are trained and that they remain in control,” he explains.

“You have to ensure that the embedded software that has been used in testing, for example, is exactly the same when it is deployed on a train or in a plane. That really is the key to the successful roll-out of a project.”

Safety is paramount when it comes to public transport, but users need to be fully aware of any changes and improvements that are made to software, an issue for many manufacturers and highlighted by recent aviation disasters.

“Simulation has a key role to play in training not only in making it more relevant but because it is easily repeatable,” Günther Siegel
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UNDERSTANDING POWER MANAGEMENT COMPLEXITY

Current x86 hardware architectures are intended to provide optimal computing performance but also require effective power management, as New Electronics discovered.

Before power management behaviours can be discussed, it is important to understand the fundamental limitations of silicon integrated circuits. The primary purpose for power management in such devices is to ensure these limitations are not exceeded so that the reliability and functionality of devices are maintained. There are many factors that affect silicon-based transistor performance, but the focus here is on the most significant factors affecting x86 processors in their typical operating ranges.

Processor frequency is possibly the most obvious performance limiting factor. Frequency defines how fast the logic of the device is clocked, and how fast instructions are then executed. Performance will not be equivalent when comparing two processors of equivalent frequency and different architecture, but it is generally true that increasing frequency will increase execution performance.

Faster switching of the transistors requires increasing voltage to overcome the resistive and capacitive elements of the transistor. However, higher voltage increases ageing effects, putting practical limits on voltage application to ensure product longevity. Faster switching of transistors also generates higher currents as those capacitive elements are charged and discharged.

The combination of Ohm’s and Joule’s laws teach us that all this voltage and current generates power, and that both parameters have a direct relationship with power. In fact, the reality is that most processor frequency limitations also boil down to power or current limits. Faster switching of transistors increases current and may also require increasing voltage and doing either will increase power. Power limits are often the most significant performance limiting factor and as a result, modern processors, based on the x86 architecture, tend to be power limited rather than frequency limited with heavy workloads.

As the processor operates, consumed power is converted to heat. Manufacturers will set maximum die temperatures for their products that must be followed. Maintaining this temperature limit is an important task for the power management entity in the processor.

Leakage power

Another basic principle of silicon transistors is that they leak current across junctions and to the substrate. The amount of leakage current in a processor of a particular process type will vary largely by applied voltage and temperature and it can become quite significant in today’s high-performance processors. All this leakage current creates additional power that must be counted as part of the device’s total power consumption.

Naturally, leakage power effectively reduces the amount of the device’s total power envelope that can be consumed as active power.

Workload power density

Understanding power management behaviour in complex microprocessors also requires understanding the concept of workload power density. This concept essentially means that different workloads will generate different amounts of power consumption in the processor, even at the same utilisation level. As an example, one can imagine that a complex floating point calculation will trigger more transistor activity in the CPU than a simple data movement operation. The potential difference in power...
between workloads becomes even larger when considering that nearly all x86 microprocessors sold today are multi-core, and most have integrated many other functions that were previously external. Integration of the graphics processing unit (GPU) is the most significant, as it is a very large processing core on its own.

The data in this figure show that the power consumption of less power-dense workload was only 57% of Prime 95 with a single CPU core active. When extrapolated across multiple physical cores, it is easy to see that power variation by workload can grow quite large.

**Defining power limits**

Definition of the maximum power consumption is a common starting point when defining processor models. manufactures choose power levels to address various use-cases with differing power restrictions, and performance (i.e. frequency) is largely derived from that. x86 processors are largely marketed by their Thermal Design Power (TDP), even though it is a specification related to the thermal solution requirement and not a maximum electrical power that the device can consume. Maximum sustainable power levels will be equal to or greater than TDP, depending on the product.

The power management controller of the processor monitors key parameters to ensure the processor specifications for maximum power, current and temperature are not exceeded. If changes in the operating scenario cause any one parameter to approach its limit, the controller must throttle the processor’s performance to compensate.

This throttling usually takes the form of reducing operating frequency of the core(s) consuming the largest amounts of power (i.e. CPU and GPU), as they have the biggest impact. These adjustments can happen as much as every millisecond for a very quick response to changes in the operating environment or even the workload. Since power consumption varies with the workload, one can recognise why achieving maximum frequency of a core may not always be possible.

**Device variations**

The natural result for the power limited model is that performance is maximised for each workload, but frequency is not predictable with workload changes. System designers can avoid temperature throttling by developing enough headroom into the thermal solution to ensure that the maximum temperature is never reached. After all, the maximum sustained power level is a known quantity and airflow and ambient temperature limits can be specified for the final system. Yet, two samples of the same processor model could have differences in their leakage power, causing one unit to reach its power limit at a lower average frequency even when running an identical workload under identical operating conditions.

Vendors use this difference by allowing the lower leakage units to spend more time at higher frequency, yielding better performance. Also, different processor units of the same model can have different voltage requirements to achieve a given clock frequency. This difference can be exploited by fusing unit-specific voltage vs. frequency curves into each part that enable the power management controller to minimise core voltage.

**Regulator telemetry**

Until recently, processor power management technology relied on power curves derived from actual power measurements at manufacturing test time with a reference workload. Values were programmed into the processor and combined with run-time data from complex activity monitors in the logic.

A recent change with AMD processors is the use of power telemetry data from the regulators powering the primary voltage rails. Real-time voltage and current data allow the power management unit to be much more accurate.

Doing so enables every variation of the unit that affects power consumption to be factored in along with instantaneous environmental circumstances and exploited for performance gain.
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FROM THE RACETRACK TO THE ROAD
With Moore’s Law being pushed to its limits and general-purpose CPUs and GPUs no longer able to meet the requirements of more demanding workloads computing pioneers, John Hennessey and David Patterson have suggested that the industry is on the cusp of a new golden age of computer architecture with the creation of multiple domain-specific architectures (DSAs).

The Open Compute Platform organisation (OCP) has recently seen an explosion of interest in accelerators, with proposals for a wide range of form factors to support accelerators.

Like general-purpose CPUs, DSAs are programmable. Unlike general-purpose CPUs, DSAs also contain a substantial amount of logic tailored to accelerate the execution of specific workloads, resulting in a 5-10X power-performance improvement for their target applications.

Examples include, Google’s Tensorflow accelerator, which contains large internal memories and multiply-accumulate arrays to accelerate machine learning workloads and Netronome’s Network Flow Processor which contains data movement logic and multiple processing threads to accelerate the processing of networking workloads.

While DSAs benefit from being produced on advanced process nodes, at 10 and 7nm nodes, the total cost of silicon product development may exceed $200million and as DSAs serve more focused markets, they may not be economically viable.

Conversely, while DSA development on more mature nodes is cheaper, die sizes may be so large that poor yields make DSA products too expensive.

One solution is chiplet-based product design, which has recently received renewed attention. Here, a product is implemented not as a single monolithic die, but across multiple die in a single package. AMD, Xilinx and Intel have either built or have plans to build chiplet-based products which offer two potential advantages.

Firstly, an accelerator design that requires a large die when implemented as a monolithic product, can be partitioned into multiple smaller die, each of which offers a higher yield. Data from AMD has shown that a large multi-core processor partitioned across four die is 30% more cost effective than the same product implemented as a single die.

Though each accelerator contains domain-specific logic, accelerators of all kinds contain several non-domain specific elements such as general-purpose CPUs, network, memory and host interfaces, internal memory and bus/switching logic. In the Tensorflow accelerator, for example, this domain-independent logic accounts for almost 40% of die area.

Monolithic designs reduce development cost through reuse, by buying 3rd party intellectual property (IP) for these functions. However, IP reuse still incurs significant costs.

Figure 2 shows how DSA products can reuse chiplets instead of IP. New design effort can be focused on the logic block unique to this new product, reducing development costs.

Secondly, designs composed of chiplets implemented in different process nodes, potentially further reduce costs.

Relative to a monolithic design, chiplets incur both a power and potentially a performance penalty. Data that would be transmitted on-die in a monolithic design is instead transmitted between die. Historically, off-die (and correspondingly off-package) communication has been several orders of magnitude less efficient than on-die communication. Recent advances in short-reach communication and packaging have made inter-chiplet communication achieve efficiency comparable to on-die communication and spurred a renewed interest in chiplets.

Open domain-specific architecture

Beyond power-efficient communication, the chiplets in a package have to be functionally integrated i.e. they have to work together as though they are a function implemented on a single die.

This functional integration is implemented with an architectural interface. Almost all chiplet-based products use a closed proprietary architectural interface. Chiplets from multiple companies cannot be easily assembled into an integrated product.

The Open Domain-Specific Architecture (ODSA) project aims to enable the development of domain-specific products that integrate chiplets from multiple companies by
developing and implementing an open architectural interface.

The ODSA works to define recommendations and specifications for open interfaces to enable multiple chiplets to work together as though they are a single monolithic die. Figure 3 shows the architectural interface under development. The architectural interface is a memory-semantics based logical interface that is constructed on top of the physical connectivity between chiplets. It allows all the chiplets in a package to share a common address space and allows coherent and non-coherent memory transactions between chiplets.

This enables software on the chiplets to behave as though the chiplets are a single die.

Finally, the ODSA is also working on common physical descriptions, interface operation, management and test mechanisms.

Chiplet-based products will require a workflow different from that for monolithic designs. For example, one bad die in a multi-chiplet product renders the whole die unusable.

Die will have to be extensively tested before being integrated into a package and being tested as a product - commonly referred to as the known good die problem.

IP normally sold as soft or hard macros will now be sold as die. Chiplets may in-turn require new types of IP. The ODSA aims to establish good practices to enable the efficient development of chiplet-based products.

The ODSA is also developing reference implementations to inform the development of the architectural interface and business workflow. The first target is a prototype that integrates existing die from multiple companies into a single package.

The second is a PoC that will implement the same functionality as the prototype, but with chiplets that support the new architectural interface. The prototype is a learning platform to identify business and technology issues in developing chiplet-based products – and has already highlighted several issues. For example, bump maps, normally confidential, will have to be shared all the companies building the PoC.

**Recent progress**

Since its inception in October 2018 the ODSA has grown rapidly. The group produced a white paper with contributions from 10 organisations in December. It runs workshops and in March, the ODSA was adopted as an official OCP project.

Multiple PHY technologies currently exist ranging from the highly parallel interfaces on thousands of low-speed wires to serial interfaces with very few wires, each running at a high speed.

Figure 3: Open interface for chiplet-based design

zGlue is evaluating these technologies, including beachfront bandwidth (the length of interface), energy per bit, implementation complexity, portability across process nodes and methods to match technologies to design goals. This is believed to be the first public cross-PHY analysis on common objectives.

Brian Holden from Kandou has proposed a PCIe PIPE abstraction so as to enable a common architectural interface to support multiple PHY layer technologies.

Another proposal from GlobalFoundries and Aquantia is for a new open PHY layer. The proposed interface, derived from the well-known high-bandwidth memory (HBM) interface, can be easily implemented in multiple process nodes.

Quinn Jacobson from Achronix, Jawad Nasrullah from zGlue, Marc Verdiell from Samtec and Larry Zu from Sarcina have developed a design and development plan for the ODSA prototype that targets networking and storage applications.

The ODSA’s objective is to create a marketplace of chiplets from multiple vendors. With these tools, developers can assemble domain-specific architectures to target specific applications at specific power and performance targets by assembling best of breed products from the marketplace.
SECURITY THROUGH MODULARITY

As more connected devices appear, so the concept of modularity is being used to tackle the problem of security. By Neil Tyler

While the world of connected devices continues to grow unabated, the issue of building security into these devices has tended to be an afterthought, in many cases, and the impact of this is being felt on a daily basis by both consumers and companies.

Whether device security and brand protection, operational cost containment or the user experience, the costs associated with poor security are growing exponentially and it remains a fact that despite the amount companies are willing to spend on R&D, too many are still failing to invest in security to ensure their IoT devices are made secure.

According to Dan Potts, CEO of Cog Systems, attitudes towards security remain diverse.

“In truth, attitudes towards security, and the risks associated with it, are hard to measure, especially when companies are not looking at, or addressing the issues around security. “In terms of the companies we work with there’s a real mixed bag out there in terms of their attitude towards security. Some are blissfully unaware of security, others turn a blind eye as it is seen as a big distraction if they are trying to get ‘cool’ consumer devices to market ahead of the competition.

“Those who view security in this way are usually companies whose focus is on driving innovation and getting to market first. “Smaller businesses tend to overlook security until they are successful - when they have sold 1000s or even 100,000s of devices a hack could have a profound impact on their business - only then do they become worried about how a hack may affect their brand or a device’s functionality.”

According to Potts there is a degree of apathy, or inertia, when it comes to addressing the issue. Security, however, can’t be ignored and that is especially true for a business whose devices could be handling sensitive information and data.

“Cog, which was founded in 2014 and is based in Australia, was established to provide security for connected device architectures,” explained Potts. “We wanted to build better security from an operating point of view.”

According to Potts, the architecture of connected devices has created far too many vulnerabilities and therefore opportunities for hackers to compromise devices, resulting in a growing number of companies having to accept much higher levels of risk which can, in turn, restrict access and make life more difficult for users.

“When it comes to security we have adopted an embedded solution that’s built on the concept of modularity, as well as proactive security, trustworthiness and adaptability to enable highly secure connected devices,” Potts said.

“We look to leverage modularity in order to isolate critical functions...”
and services on connected devices and by doing so we are pro-actively securing these devices by reducing the attack surface. At the same time we are increasing reliability by eliminating single points of failure.”

According to Potts, Cog focuses on securing the kernel, data, and network as the baseline to the company’s security solution.

“We also look to isolate specific applications, operating systems, or services to further achieve a full defence-in-depth based solution. The system can scale linearly and infinitely, reducing bottlenecks while at the same time preserving performance.”

This approach not only provides high level grade security for the device but it also means that customers no longer have to worry about security – they can focus solely on what they’re best at, delivering IoT applications for their customers.

But is a failure to address the problem of security becoming a bigger issue? Potts suggests it might be and a growing number of reports point to a similar trend.

**Modular v Monolithic**

“At Cog we have a strong background in operating systems and ours is a philosophical approach when it came to security and our decision to take a more modular, rather than monolithic, approach,” explained Potts.

“From our experience with working in the connected device ecosystem, we wanted to work out how best we could help connected devices build better security from an operating point of view. The motivation was simply that we were seeing an ever increasing trend, largely mobile related to begin with but then with the Internet of Things, in which an increasing number of connected things and devices are coming to market.

“We felt that a monolithic architecture, typically Linux based, was more vulnerable from a threat perspective to attacks, and we wanted to take a more modular approach, much the same as with hardware components, so that we could improve security.

“I’ve already mentioned our philosophical approach to security and our modular approach was a result of a lot of research which encompassed componentisation, defence in depth and so forth. We wanted an approach that would enable companies to solve a variety of problems – providing them with both better engineering outcomes and more flexibility.

“We began by working with defence firms, who are highly regulated, to build the chain of trust, using encryption for example, and to productise our concept to make it more usable,” Potts explained.

“D4 Secure is the result of this work and is a software toolkit, in essence, which has building blocks to help device manufacturers quickly build in modularity; they can add data encryption etc., as well as mix and match different operating systems.

“It’s a framework for providing security and extensibility to connected devices. The architecture isolates certain system processes and capabilities by leveraging Type 1 Virtualization to separate the functions into multiple virtual machines (VMs).”

According to Potts, by splitting the system into multiple functional areas it allows for much greater operational integrity, more granular system control, and, crucially, a much reduced attack surface.

“Various rules of operation govern the interactions across functional areas and between virtual machines and these ensure that the system functions in very specific ways, as defined by the specific use case.

“Developers can use as much or as little of it to solve their problems,” he explained.

The components of D4 Secure comprise of modularity, security, value added modules and scalability.

Modularity provides multiple levels of containerisation that serve to isolate applications and components while enabling plug and play virtual machines and components, faster system development and software reuse. This approach makes it possible to securely run legacy software together with updates and third-party software, according to Potts.

In terms of security it provides storage encryption technologies and device policies that ensure defence-grade embedded security.

Additional layers of security can be added to D4 Secure to provide the highest degree of assurance that the device and data is protected, including: Full Disk Encryption (FDE) and a Nested VPN i.e. a second VPN to the operating system, to run a truly ‘nested’ VPN solution on the device, which provides double Data in Transit (DIT) protection.

Finally, D4 Secure provides scalability and the ability to concurrently run software with vastly different Operating System (OS) and platform requirements as well as run a common set of software over a variety of different hardware devices.

“This speeds up development by eliminating the need to refactor or rewrite old code and also easily supports new hardware,” according to Potts.

Cog Systems is now engaging with some of the world’s leading companies including Qualcomm and Arm.

“Our aim is to secure the edge and allow people to innovate using our high performance virtualisation capabilities. We’ve just partnered with Qualcomm and will be embedding our software into their Snapdragon chips – what we provide device makers with is a very high level of security, that doesn’t impact the device’s performance due to the use of our modular approach,” explained Potts, who concluded: “No matter what type of business you are, our approach enables you to very quickly get away from security and get back to focusing on what you, as a company, do best which is innovate and bring products to market.”
An estimated 285 million people in the world are visually impaired, this includes legally blind and visually impaired persons (VIP). Yet, for the last two decades there have been no new technology innovations geared towards these groups, according to ‘Dot’, a braille smart watch producer.

“Right now, technology for VIP is expensive, bulky and often limited,” Ahrum Choi, the Director of Social Impact at Dot says. “Approximately only 5% of VIP worldwide have the privilege of owning braille devices. Educational and day-to-day life has, therefore, remained severely limited.”

Dot intends to alleviate this “digital divide” between visually impaired and sighted communities by providing a technology which is inclusive, easy-to-use and accessible.

The concept for such a focus was inspired by Dot’s CEO Eric Ju Yoon Kim’s observation during his time at university. Kim noticed that while most of his peers used tablet devices, a blind classmate was forced to lug around a large textbook – which took considerably more effort.

According to MIT, less than 1% of all texts have braille translations. This is because embossing paper to form the bumps is a lengthy process. Take the bible for example; in braille format it spans around 40 books. It’s also expensive to create. A single line of braille typically costs around $3-5k.

Moreover, when used over time, braille dots get worn out, making it tricky to differentiate between the shapes/patterns.

Although visually impaired-friendly features are available on most tablets, accessibility, according to Kim, remains a glaring issue.

Dot was founded in 2015, with the mission to innovate the auxiliary equipment market for the disabled by developing lower-priced, lighter products that facilitating high-efficiency operation.

The main goal in development was to increase affordability and the development of Dot’s own Active Braille Technology made this possible, reducing the size and cutting production costs by more than ten times, increasing speed and keeping energy consumption low.

The Dot Smartwatch is seen by the company as an entry device into the assistive technology market.

Based on its technology, a low-price ‘Dot Mini’ for developing countries, integration into utilities like ATMs, and a ‘Dot Pad’ are already in development for release in 2017/18.

Dot was developed in close relationship with Braille education institutes all over the world, to deliver a final product that fits the actual needs of blind and VI people.

Key to its technology is the electromagnetic actuator, which the company was successful in mass-producing after several years. The team created a micro actuator – a microscopic servomechanism that creates and then transmits energy so to operate a mechanism or system, and developed this using electro-magnetism, that is, the interaction of electric currents or fields and magnetic fields.

“This is different from piezo-electric actuators – the existing technology used in braille tech – mainly due to its size and weight,” explains Choi. “Our technology is 20 times smaller and 10 times lighter. This also means it’s 10 times cheaper when compared to existing braille cell technologies. Dot cell is the smallest, most cost-efficient, and the most mobile technology for electronic Braille displaying.”

Choi continued: “This actuator is the core behind all of the company’s devices, including its first success, the Dot Watch.

“This wearable device was the world’s first braille smartwatch for the
blind. Before this, a VIP would have to open a watch lid and touch the hour and minute hands in the dial to know the time,” explains Choi.

“There are several issues with this,” Choi adds, “because the hands move when you touch it, and if you are not sensitive with your fingers it’s difficult to actually read the time. This method also makes it hard to determine the precise time. Our product, however, allows users to read the exact time in braille.”

Not only that, but users can also receive notifications and messages, like a typical smart wearable.

The Dot Watch is connected to a user’s smartphone via Bluetooth and features 24 shifting dots and four pins that are powered by magnets and electrical signals. The information is relayed from the phone into braille onto the “refreshable” watch display. In other words, as they receive information, the pins rise up from the ‘dots’ – sort of circular spots on the watch face – to create the appropriate pattern/s.

Despite this small number of pins, the refreshable display enables users to read entire notifications sent to the watch. Dot Watch wearers simply read up to the last letter on the display, then remove their finger, the integrated touch sensor notifies the pins to refresh and bring up the next series of letters. This means personal messages can be read - across the surface of the 43mm radius circle - in private. Unlike traditional voice-assistive technology, which is found in most current smartphones, that reads what is on screen out loud to the individual.

“We have an in-house research centre in Korea which focuses purely on the actuator. It took us nearly 3 years to make dot cells, but in 2016 we succeeded and were able to proceed with the launch of the Dot Watch,” says Choi.

**Vibration patterns**

To indicate different types of notification (e.g., a phone call and a message), the watch also features different vibration patterns. Wearers can then use the buttons on the side of the watch to read select information.

The device comes with the option to have scrolling automated or manual to make it accessible to both proficient and slower braille readers.

As for the future, the company has already expanded with the Dot Mini - the Kindle for the blind, and the Dot Pad - the iPad for the blind, as Choi describes them.

The Dot Mini is designed to enhance the vision of supplying educational devices to the visually impaired, with a focus on children in developing countries who are not able to afford costly devices.

While the company intends for the Dot Pad to be the next product to make an impactful social difference in the areas of education, employment, and access to information for the blind and visually impaired.

“In a world of video content and images,” Choi says, “the information gap for the blind and visually impaired is getting bigger and bigger. This is because the only technology that allows them to have real-time information in tactile are the one-line braille displays.”

Choi continues, “The problem with one-line braille display is that information can only be given linearly.” Imagine having to calculate math problems horizontally or read an entire book one sentence at a time.

“But not only that,” Choi says, “there is a limitation in expressing images, shapes and sizes with one-line of braille display.” Things like graphs or spreadsheets become impossible.

“But with a multi-layered braille display – like the Dot Pad features – we will be able to show images, graphics, 2D figures, and more. It is our most ambitious innovation so far.”

The company is currently working on its Dot Public, a smart-city solution for inclusive technology supporting information. Through this tech, the company hopes to make public infrastructure accessible - having information accessible in bus stops, public buildings and all kinds of transportation.

**With only 5% of visually impaired people having access to braille devices, education and day-to-day life has been severely limited.”**

Ahram Choi
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