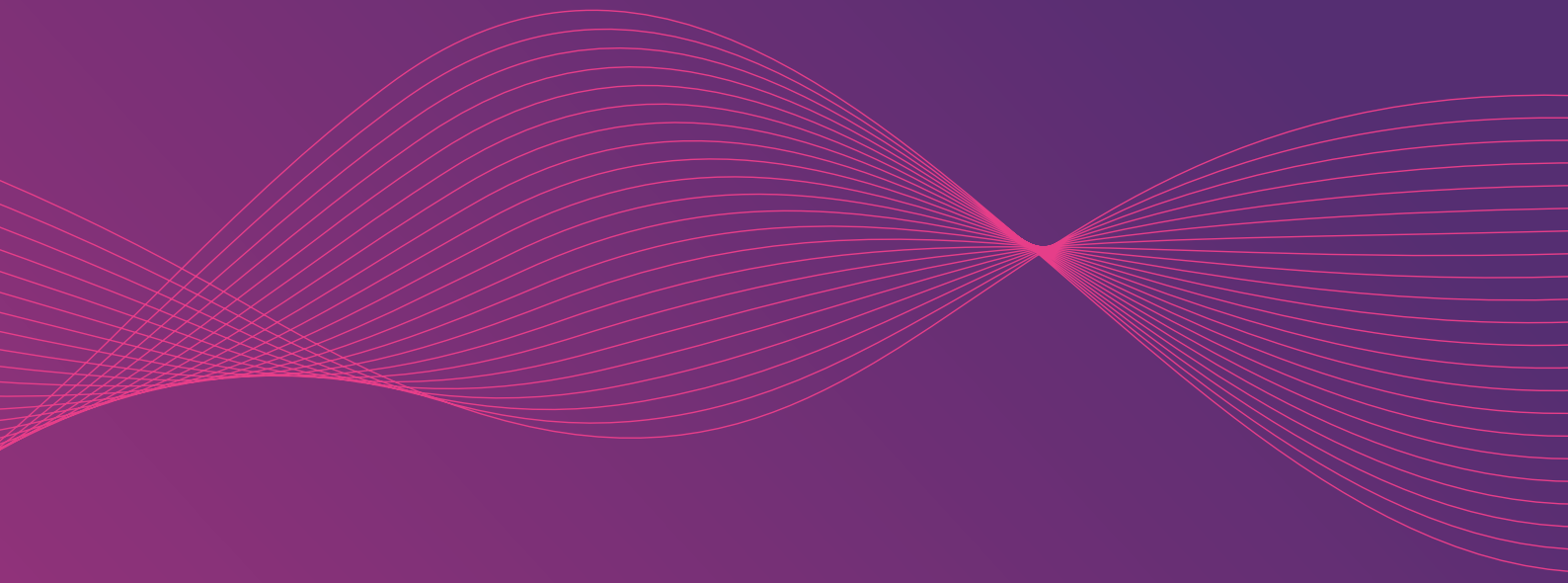
csa.catapult.org.uk

CATAPULT
Compound Semiconductor Applications

# Annual report 2022–23



We work with Innovate UK

UKRI Innovate UK

# Overview

**CSA Catapult is the UK's authority on compound semiconductor applications and their commercialisation.**

# About us

## Our vision

Our vision is for the UK to become a global leader in developing and commercialising new applications for compound semiconductors.

## Our mission

As a Catapult established with investment from Innovate UK, we are here to work with a range of industries to grow the contribution of compound semiconductor technologies to the UK economy.

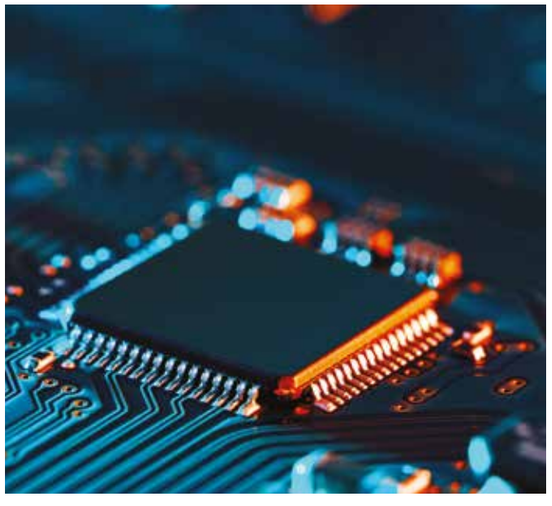
UKRI Innovate UK

## How we support industry in the UK

We help a wide range of industry sectors bring their next-generation compound semiconductor-based innovations to market. We also help companies to start using compound semiconductors to make their products – and, therefore, the UK – more competitive.

Our support removes barriers to innovation and commercialisation by creating interventions, minimising risk, and accelerating the route to market through:

- **the world-leading technical knowledge and expertise of our team**
- **our extensive, cohesive research and capability network**
- **the world-class, state-of-the-art facilities at our Innovation Centre**
- **our team's specialist market intelligence and commercial expertise**





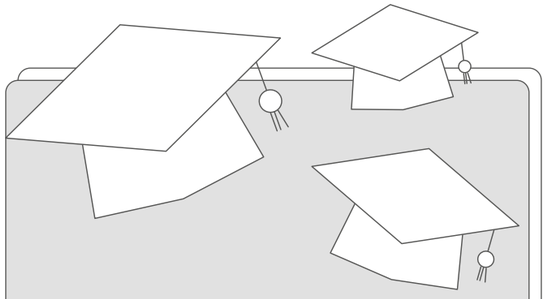
## The industries we support

- Transportation
- Clean energy
- Smart industry
- Digital communications
- Defence and Security
- Space

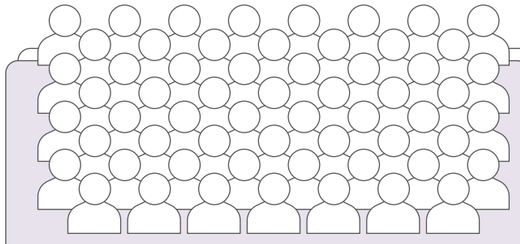
## Our areas of expertise

- Power electronics
- Radio frequency and microwave
- Photonics
- Quantum
- Advanced packaging

## Our team

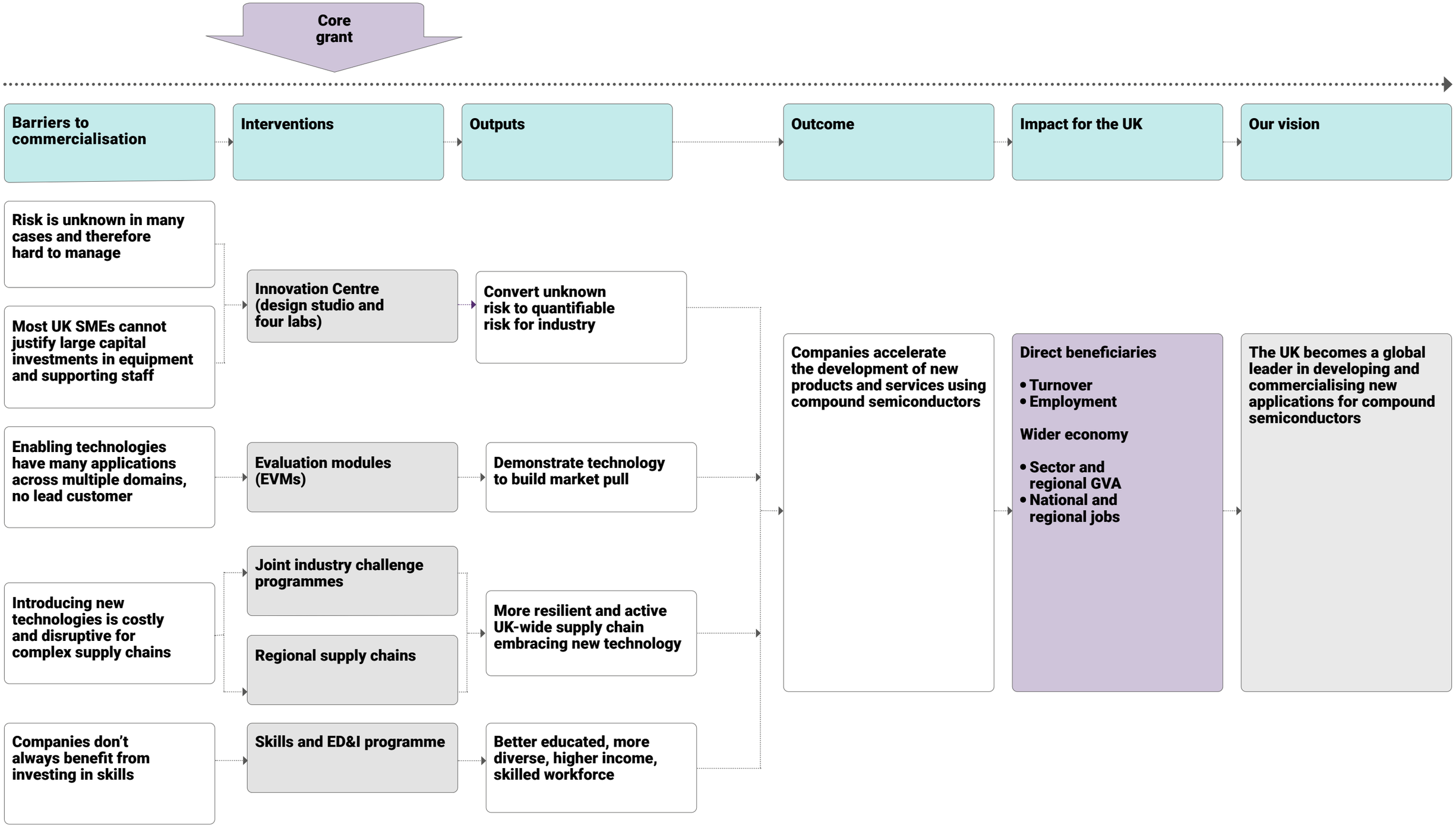


**29 PhDs**



**93 employees**

# Our impact model



# Our impact

**We leverage research, eliminate barriers, minimise risk, accelerate routes to market and attract investment for our collaborators in industries where compound semiconductor technologies have transformative capabilities.**

We help organisations develop new and improved products, identify new markets and stimulate demand for compound semiconductor technologies across the UK supply chain. We help people acquire new skills, and policy makers form future perspectives.

We continually monitor and evaluate the impact we have, through research, project reviews and case study development.

**During the summer, we surveyed our customers to understand our impact, with the following key findings:**

**100%**

said they would work with CSA Catapult again.

**89%**

of those who responded said they would not have been able to progress with product development, or it would have taken longer or cost more, if they had not worked with CSA Catapult.



**71%**

secured private sector funding as a direct or indirect result of working with CSA Catapult.

**38%**

secured public sector funding because of their direct or indirect engagement with CSA Catapult.

**80%**

have been able to develop new partnerships.

**36%**

agreed they have stronger international links.

**53%**

agreed they have been able to target new markets because of working with CSA Catapult.

**56%**

agreed that they have been able to attract greater investment for compound semiconductors.

**Using our analysis, we also examined the impact that working with CSA Catapult has on SMEs' ability to attract private and public sector funding. We then compared these results with our counterfactual group of SMEs (that we have not worked with). It shows that:**

- on average, since engaging with CSA Catapult, companies leveraged annual private investment of £85m and secured £26.5m of annual public sector investment. The private investment figure is particularly significant when compared to our counterfactual group, who on average raised £46m annually from the private sector and relied on £10m of public sector investments

| | Total average annual private sector funding | Total average annual public sector funding |
|---|---|---|
| SMEs we have worked with | **£85m** | **£26.5m** |
| SMEs we have NOT worked with | **£46m** | **£10m** |

**Our analysis also compared the percentage of SMEs that work with us who secure external funding with our counterfactual group who haven't worked with us:**

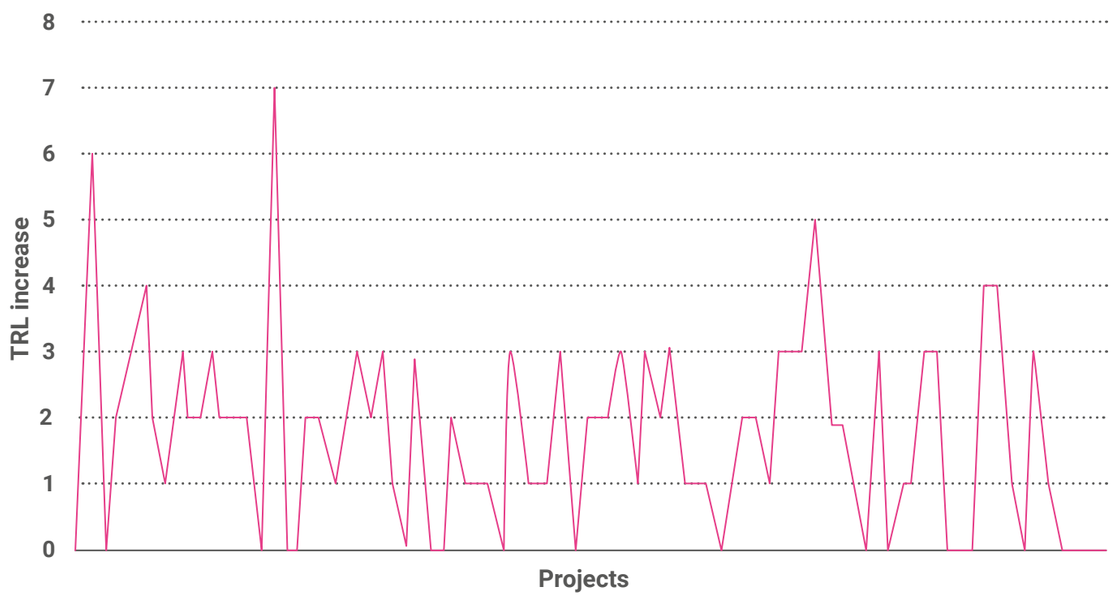
| | % who secured private sector funding | % who secured public sector funding |
|---|---|---|
| SMEs we have worked with | **36%** | **71%** |
| SMEs we have NOT worked with | **16%** | **46%** |



We analysed the data we collect to assess our projects' Technology Readiness Levels (TRL), monitoring research and development (R&D) growth as a pathway to measuring value for money. TRL are a type of measurement system used to assess the maturity level of a particular technology, ranging from 1 (basic principles) to 9 (actual proven system and operational). While this information is still being collected in full across all our projects, we can share the following graph as an indication of what it will show us:

The graph shows that we typically help companies advance their TRL by one to three levels, helping more products to commercialisation.

## Increase in TRL



# Outputs and outcomes

**£18.6m**

CR&D projects won

**2,827**

Jobs forecast

**207**

Industrial collaborations

**10**

International partners

**54**

Academic collaborations

**£381m**

Direct leveraged investment

**63**

R&D projects

**26%**

Academic partners in projects

# Chair's statement

**This financial year was a year of significant growth for CSA Catapult. We continued to focus on the two key parts of our strategy – Net Zero and Future Telecoms – and embarked on a new partnership in power electronics, machines and drives with Siemens.**

We are delivering around 140 projects for UK industry. We continued to build our skills programme, a key element of our strategy as we expand across the UK. Our commitment to achieving equality, diversity and inclusion (ED&I) remains fundamental to our work, not least because we know that diverse teams mean better innovation.

Our growth is also good news for UK industry: a key part of our role as a Catapult is to help develop and accelerate technology using compound semiconductors, essential to driving the transformation of our transportation, energy and data needs now and in the future.



Compound semiconductor applications are essential to the delivery of Net Zero, reducing energy losses for several key industry sectors, and for resilient telecoms networks in the UK in the future. They will increase the efficiency of electric vehicles and reduce energy losses from solar panels and wind turbines. They will transform high-speed communications, including 5G and 6G, creating more efficient and less energy-intensive telecoms networks, and will help alleviate the huge amounts of energy currently consumed by our data centres. Compound semiconductors will also be a key enabler in the next generation of quantum applications, such as computing and communications.

The major global opportunities are clear – and the UK must seize and exploit them over the next ten years, for national resilience as well as economic prosperity.

In precise terms, the global market is expected to grow from $123 billion to $252 billion by 2030, so the size of the prize is substantial: a modest 1% increase of the UK's global semiconductor market would deliver an additional $3 billion to our national economy; a 3% increase in share by 2030 would generate $8 billion.

While growth of the UK share of the global market by just a modest amount will both benefit our companies and drive our GDP (gross domestic product), its successful delivery depends on maintaining the UK's academic lead and aligning the industry with the greatest global opportunities. That requires focused, sustained co-ordination across the compound semiconductor sector, which CSA Catapult is in place to deliver.

In May 2023, the UK government published its first National Semiconductor Strategy, which emphasises the critical role that semiconductors will play in shaping future technologies, underpinning national security and stability, and levelling up our communities. We are encouraged to see the strategy focus on the UK's strengths, such as advanced packaging, where CSA Catapult has significant expertise and capability.

Much of our focus in 2022–23 was on helping establish new clusters and supply chains in Bristol, the North East of England and Scotland to support the UK's compound semiconductor ecosystem. I look forward to reporting on their progress in the next annual report.

I would like to thank Trevor Cross and Jonathan Lyle, who left the Board this year, for their valuable contribution to the company. We welcomed four new non-executive directors this year as CSA Catapult moves into its next five-year period: Debbie Wilkinson, Lorraine Rienecker, Layla Moran MP and Tammy Lillie. We also welcomed back Becky Jacobs, our Chief Financial Officer, from maternity leave.

I would like to thank them and the rest of the Board, the executive team and all our colleagues for delivering the Catapult's multiple successes over the past year.

**Rob Bryan**
**Chair**
November 2023

# Chief Executive Officer's statement

**Our story this year is one of expansion to underpin the growing success of the UK compound semiconductor sector and build for its promising future, with support and collaboration from government, industry and academia.**

We remain focussed on Net Zero and Future Telecoms, areas where the market is the most attractive and where the UK has the capacity to capitalise.

Throughout the year we continued to deliver at pace against our four strategic areas: our technology centre of excellence; developing supply chains and skills; supporting UK clusters; and growing our own commercial income.



We also delivered our first strategic partnership with Siemens to accelerate the development of leading-edge power electronics capability. This partnership model – a first for both companies in the UK – focuses on the development of disruptive power electronics and on building advanced skills.

We developed a new skills partnership in Wales with UK Electronic Skills Foundation (UKESF) called 'Spark their Imagination, power their future', which is funded by Innovate UK for schools and colleges in Wales, due to be launched in 2024. This is a positive step forward for our skills programme, so that learners across Wales will gain a greater understanding of the opportunities in electronics. We also welcomed our new group of interns to spend a year at the Catapult, an important part of our skills strategy, where we help support UK engineers of the future.

We provided expert evidence to the BEIS Select Committee Inquiry into Semiconductors and hosted a wide range of visits from UK government ministers and officials from both the UK and Welsh governments. The National Semiconductor Strategy published by the UK government in May 2023 presents significant opportunities for growth and innovation across the industry with the potential for huge economic benefits through company support, job creation and skills development across the UK.

With the support of Innovate UK, we expanded our network of regional clusters that work with industry on the ground, helping them bring new innovations to market. These were in Bristol, the North East of England and in Scotland.

For the second year, the Catapult was recognised and certified as a 'Great Place to Work'. Our continuous commitment to ED&I is vital to our success and this was underlined when we signed the cross-Catapult ED&I Charter in March 2022.

The power of compound semiconductors cannot be underestimated. They are transforming the technology we use today and shaping the technologies we will use tomorrow.

I am very pleased to have agreed the next five years' grant funding agreement from Innovate UK and we look forward to working collaboratively with them in the future.

As we continue to work towards the UK becoming a global leader in developing and commercialising new applications for compound semiconductors, I would like to thank the colleagues of the Catapult for their continued commitment to delivering this vision.

**Martin McHugh**
**Chief Executive Officer**
November 2023

Committed Member of Inclusive Employers

Great Place To Work. Certified NOV 2022–NOV 2023 UK

# This year's highlights

May 2022

## Building a bilateral telecoms ecosystem between India and the UK

CSA Catapult led the Future Telecoms Programme delegations to New Delhi and Bangalore, including representatives from government, industry and academia. These visits demonstrated the value of the UK's innovation ecosystem, and its ability to work collectively to translate disruptive technologies and innovation into commercial products and services. During the visits we saw a strong desire to collaborate in wide-ranging areas, including cyber security, electric vehicles, semiconductor supply chains, optical communications, security and satellite technologies.

In June 2022, the Secretary of State for Wales welcomed the UK and India Telecoms delegation to Cardiff.

July 2022

## Partnership with Siemens plc to establish its power electronics innovation hub in the UK

We entered a strategic innovation partnership with Siemens plc in Newport, South Wales, to accelerate the development of leading-edge power electronics capability. This partnership model, a first for both companies in the UK, focuses not only on the development of disruptive power electronics but also on building advanced skills in the UK.

November 2022

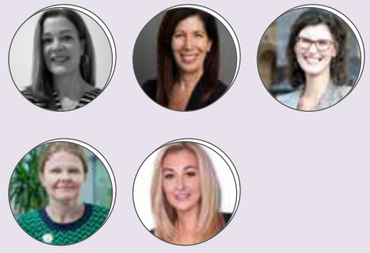
## Partnership with Cardiff University to improve production of wide bandgap power electronic converters using AI

We developed a partnership with Cardiff University to develop a new and more efficient way of modelling and designing power electronic converters using artificial intelligence (AI). The new method has reduced technology design times by up to 78% compared to traditional approaches and was used to create a device with an efficiency of over 98%. Our joint team's findings were published in the IEEE *Open Journal of Power Electronics* and IEEE *Transactions on Power Electronics*.

January 2023

## New board appointments announcement

The Catapult expanded its Board with the appointment of four new non-executive directors: Debbie Wilkinson, Lorraine Reinecker, Layla Moran MP, and Tammy Lillie. Becky Jacobs returned to her role as Chief Financial Officer and an executive director after a period of maternity leave. The new directors' role is to work alongside their fellow Board members to support the corporate governance of the Catapult, applying their skills, judgement and expertise to make informed decisions regarding future strategy.



January 2023

## Appointment of Nick Singh as Chief Technology Officer

A key appointment to the Catapult, Nick leads the strategic and technical direction of CSA Catapult's four key technology areas – power electronics, RF and microwave, photonics and advanced packaging – as well as supporting the delivery of our overall strategy.

January 2023

## Power electronics MoU signed with Cardiff University

The Catapult and Cardiff University signed a memorandum of understanding (MoU), that lays the foundation for a long-term partnership to promote research in areas of common strength and create a lasting public impact in the UK and beyond. It sets out a framework to develop joint research projects and funding bids, exchange staff, share facilities and equipment, develop teaching initiatives, and create a skills and talent pipeline.

February 2023

## Project to simulate microgrid for electric HGVs

CSA Catapult joined a consortium working to explore the potential of a simple scalable and low-cost DC microgrid to charge electric heavy goods vehicles (eHGVs). The consortium, led by Syselek and including CSA Catapult and Levistor, aims to simulate an innovative and grid-integrated DC microgrid system that could be used to charge eHGVs at depots aligned with the scheduling of daily fleet operations.



February 2023

## Sparking the imagination of future engineers

CSA Catapult's team of interns spent two days at Cardiff Science Festival 2023 inspiring around 400 young people and parents.

March 2023

## Celebrating future skills

CSA Catapult hosted the Catapult Network and all our partners at our Shaping Future Skills Conference. A year on from signing the Inclusivity in Innovation Charter, the conference explored the links between skills and equality, diversity and inclusion, and discussed their essential role in maintaining a thriving and impactful research and development landscape.

# Growing the UK compound semiconductor industry



**Since the Catapult was set up five years ago, we have delivered over 63 collaborative research and development projects with 162 partners that have transformed the UK's electronics sectors, from advanced electric vehicles to remote monitoring of rail infrastructure.**

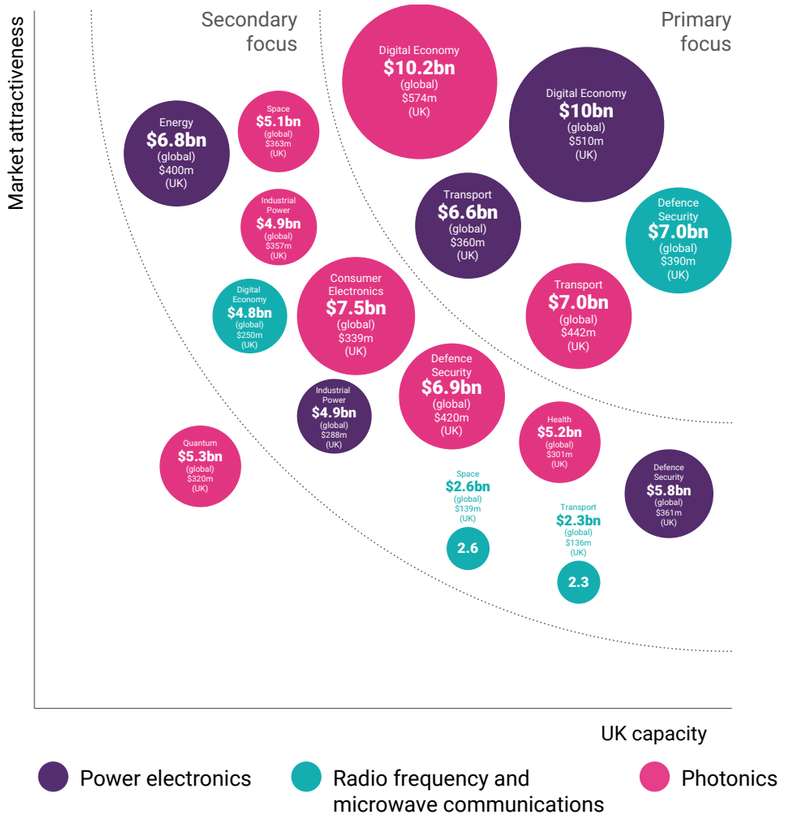
By the end of the financial year, we have delivered nine projects supporting supply chains and clusters, involving around 39 partners and with a total value of £3.5m.

We continued to strengthen our team of around 100 talented colleagues who hold 29 PhDs, as well as expanding our state-of-the-art Innovation Centre with unique facilities.

We have identified Net Zero and Future Telecoms as the most attractive sectors in which the UK has the greatest capacity, and where there is potential for considerable market growth.

In the digital economy market, power electronics will help improve the energy efficiency of large-scale data centres and photonics will be required for the next generation of optical communications and systems.

In the transport sector, power electronics will enhance the performance and charging of electric vehicles while photonics will be used in vehicle sensing and monitoring.



# Future Telecoms and quantum



**Building energy-efficient and resilient telecoms supply hardware for the UK is a priority for government.**

And it is compound semiconductor applications that will transform high-speed communications, such as 5G and 6G, by creating more efficient and less energy-intensive telecoms networks. They will also help alleviate the huge amounts of energy currently consumed by our data centres.

In 2022–23, with support from Innovate UK, we established a Future Telecoms Hub in Bristol to support the growing number of local companies and academic research. We have also identified significant opportunities for the Catapult to help companies developing quantum hardware.

Case study:

## Secure 5G: accelerating 5G open radio access networks (Open RAN), for new telecoms networks to meet the UK's future communications needs

### The opportunity

Open-RAN offers more open and accessible 5G network architecture, which will improve the UK's competitiveness and network flexibility and reduce costs. Plus, more network operators and enterprises are choosing Open RAN 5G networks as it avoids them having to be locked in to using large vendors who currently offer highly proprietary solutions. At the same time, this diversification of the supply chain enables the development of more innovative and integrated technologies.

As these Open RAN mobile networks become more prevalent, larger and more complex, there is a need for solutions that are both inherently more secure and have the flexibility to adapt to emerging threats with far greater agility.

The aim is to reduce costs, while accelerating the pace of innovation, enabling faster roll-out of services and more secure communications via a UK sovereign supply chain.

### Our role

CSA Catapult led the collaboration between all the partners, and brought expertise, know-how and experience to the project.

### Outcomes

The Secure 5G project built a flexible platform that enabled companies to roll out and maintain their own quantum-safe private networks, with targeted applications for Industry 4.0, mobile edge computing (MEC), the Internet of Things (IoT) and highly secure environments such as defence.



**Dr Ebrahim Bushehri**, Lime Microsystems CEO, commented: "*With the frequency bands allocated for mobile private networks (MPNs) varying from country to country, we see a significant opportunity for software-defined radios (SDR) and wideband PA technologies for frequency agile radio access networks, which is at the heart of Secure 5G. The use of general-purpose processor (GPP) plus commodity Linux O/S platform meanwhile has accelerated the integration of cutting-edge quantum-safe cryptography, providing an ideal solution for MPN deployments worldwide.*"

**Dr Mike Roberts**, Technical Director and co-founder of Slipstream Engineering Design, said: "*Slipstream Design has been delighted to secure funding as part of this consortium to support our research and development activity in the telecommunications sector. As an SME, it was a major boost and allowed us to conduct highly innovative 5G product development with the backing of government. Power-efficient wideband operation is an area that constrains the flexibility of current telecommunications hardware. We aim to break through this technology barrier to enable wider network coverage in a more efficient and agile way.*"

**Sarah Gregory**, Commercial Director of Slipstream Engineering Design, said: "*We have felt privileged to work alongside the other consortium members as well as DSIT in a truly collaborative project. The resulting wideband power amplifier technology developed by Slipstream Design has the potential to optimise radio unit hardware, reducing the need for variants in a way that speaks to the sustainability aims of the telecommunications sector.*"

**David Williams**, Arqit founder, Chairman and CEO, said: "*Arqit recently co-authored the GSMA white paper on post-quantum security and we are pleased to deploy our unique symmetric key agreement platform into this 5G project. Technology models for 5G and IoT are evolving rapidly but the edge cannot be secure without a new approach to encryption. Arqit delivers that.*"

Case study:

# Developing radio frequency (RF) and microwave communications test and verification capability to grow UK supply chains

## The opportunity

This year, the Catapult expanded its RF testing capabilities to cover characterisation and verification of devices spanning frequencies up to 67 GHz, covering 5G bands, both sub 6 GHz and mmWave, and resilient communications frequencies.

The testing focus is on power amplifiers, a key constituent part of the RF front-end electronics that provides the last stage of signal amplification before transmission over the air. Testing provides benchmarking of components to verify performance against specification sheets prior to system design and manufacture with linearity, efficiency and power being key verification metrics.

## Our role

In-depth characterisation can determine the optimum operating conditions to iterate improved designs and maximise the performance of the amplifiers. This year, a major addition to the Catapult's testing portfolio has been an Innovate UK-funded investment in a new load-pull test bed at our Future Telecoms Hub in Bath and Bristol Science Park. This will enable more advanced evaluation of radio frequency and microwave communications telecoms devices, enabling industry to develop improved hardware.

## Activities

Following its installation, the operating procedures were optimised and standardised and the team were trained to use the equipment. Automated testing began to improve throughput. Four key test beds have been set up to span low and high frequency ranges and on-wafer and connectorised devices.

RF equipment is highly sensitive, so it was necessary to calibrate the configuration of cables and connectors to deliver repeatability of results, and to ensure adherence to standard operating procedures across the team for consistent results.



## Outcomes

The RF and microwave test lab has been a key enabler in delivering the two Department for Science, Innovation and Technology Future RAN Competition (DSIT FRANC) projects in Secure 5G and ORANGaN.

A key objective of ORANGaN has been to advance the UK's RF GaN supply chain. The Catapult's role has been to test iterations of devices fabricated and supplied by INEX and provide process feedback to improve their manufacturing capabilities.

On the Secure 5G project, Lime Microsystems has developed a secure, private 5G network with interoperable components and software-defined radio. Their architecture relies on compatible hardware – a broadband power amplifier developed by Slipstream Design Engineering and characterised by CSA Catapult during its design lifecycle to improve the performance and optimise the interface electronics.

## Next steps

To validate our measurements further by benchmarking against multiple test facilities to verify their accuracy.

Case study:

## SPLICE – enabling ground-breaking 3D gas-sensing technology to reduce the effects of climate change

### The opportunity

Methane leaks are posing a major societal and environmental problem for the oil and gas industries.

Leaks can not only cause a serious public health hazard but are a significant contributor to climate change.

As the main component of natural gas, methane is nearly 100 times as potent as carbon dioxide at trapping heat in the atmosphere, accounting for about 20% of global greenhouse gas emissions.

It is estimated that the global natural gas industry leaks around 3% of its total supply each year, with a value of more than $30 billion. Projections show that natural gas leakage will make up more than 10% of global carbon emissions in the coming decades.

Effective ways of visualising, monitoring and detecting natural gas leakages at industrial sites are therefore of upmost importance, yet current solutions remain expensive, labour intensive and unsuitable for widespread application.

This has accelerated the search for a safe and affordable system that can be easily implemented to provide fast and reliable gas monitoring over a large area.

### Our role

The Catapult was a key member of the SPLICE project, an Innovate UK project consortium, working as part of the National Quantum Technologies Programme, designed to bring a state-of-the-art gas-imaging system to full commercial readiness.

Led by UK-based QLM Technology, the project also included Aston University, Bay Photonics, BP, Land Instruments International, National Grid Gas, National Physical Laboratory, STL Tech, University of Bristol and University of Sheffield.

The aim of the SPLICE project was to commercialise QLM's revolutionary single photon quantum gas sensor through research, development, field trials and manufacturing optimisation.

QLM's Tuneable Diode Single Photon Lidar (TDSPL) sensor system offers a significant advance over existing gas-imaging systems in terms of sensitivity, range, small size and low cost.

The Catapult helped test several commercially available single photon detectors and optical amplifiers to determine which ones performed best in the gas-imaging system. The Catapult also performed environmental tests on the optical amplifiers to determine how well they performed in extreme conditions, such as high and low temperatures, and to test the limits of their operation.



### Outcomes

QLM Technology have signed a collaboration agreement with SLB (formally known as Schlumberger), one of the world's largest oil and gas services companies, who provided lead investment in a £12m round of Series A funding.

Existing investors in the technology, such as Green Angel Syndicate, Enterprise 100 Syndicate, Development Bank of Wales and Newable Ventures, also joined in this round of funding.

QLM's gas-imaging sensor will be part of the new SLB End-to-end Emissions Solutions (SEES) business offering for the oil and gas industry, complementing existing satellite, aeroplane, and drone-mounted sensors offered by SEES.

QLM Technology are creating jobs and expanding their operations for manufacturing in Cardiff and Paignton, UK, and have established a site near San Francisco, USA, to support international sales and operations.

Through a series of new funding agreements with SMEs and start-ups in the UK, QLM is also establishing a supply chain to help support the development of its ground-breaking product.

*"Working with CSA Catapult on the SPLICE project has provided us with a good understanding of, and confidence in, the critical compound semiconductor laser and detector components that underpin our quantum gas LiDAR camera. Making these components in the UK is the next step in our development and we are working with CSA Catapult to enable that."*

**Murray Reed**

CEO QLM Technology

# Accelerating the UK towards Net Zero



**The Catapult is supporting the development of supply chains to help the transport industry decarbonise. The opportunitiy is significant, with the UK market in power electronics, machines and drives (PEMD) predicted to be worth £5 billion by 2025.**

The Catapult is one of the four Driving the Electric Revolution Industrialisation Centres in the UK, funded by an £80m investment from the Industrial Strategy Challenge Fund.

Case study:

## Driving the Electric Revolution Industrialisation Centre for the South West and Wales

### GaNTT – Gallium Nitride Trench-FET Development for Automotive Power Applications

### The opportunity

The Catapult is playing a critical role in the development of supply chains for electric vehicles in the UK and across the globe. That market comprises power electronics, machines, and drives (PEMD).

### Our role

This year we delivered three projects on behalf of the Driving the Electric Revolution Challenge, one of which was gallium nitride trench-FET Development for Automotive Power Applications, known as GANTT. As a partner, we undertook the development of a new gallium nitride (GaN) process platform for automotive power electronics.

### Outcomes

Our main areas of focus have been:

- **the development of a UK source of thick GaN epi substrates required for the vertical device**
- **damage-free GaN etching to form a suitable vertical channel**
- **successful materials integration of the gate dielectrics and gate electrode**

The project is highly innovative from a design perspective and Swansea University has filed a patent application for the device design.

DER Industrialisation Centre South West & Wales

Delivered by UKRI Innovate UK

*"The Driving the Electric Revolution Challenge, that is delivered by Innovate UK, is significantly impacting the semiconductor industry by delivering innovative collaborative projects that are unlocking new technological capabilities. Working alongside the Compound Semiconductor Applications Catapult and many other partners, we are catalysing the transformation of the power electronics, machines and drives industry in the UK and supporting businesses mentioned throughout this annual report to grow and succeed."*

**Professor Will Drury**

Interim Executive Director
Digital & Technologies, Innovate UK



Case study:

## High T Hall – developing new supply chains for sensors for power electronics

### The opportunity

The vision for this project was to develop and provide a supply chain for high-temperature operation Hall effect sensors. These detectors can measure high-frequency electromagnetic field switching for electric motors and drives, using a completely innovative Hall sensor element made from graphene. Until now it has not been possible to create monolayers of graphene suitable for electronic devices at scale, which has inhibited the commercial uptake of graphene electronic devices.

In this project, Paragraf used its proprietary graphene material and subsequently processed it using standard manufacturing techniques, resulting in a fully packaged graphene Hall sensor product. The project achieved the aim of graphene Hall sensors working at elevated temperatures proven through testing in end-user applications.

### Our role

Paragraf created graphene that sits on a semiconductor wafer and is suitable for standard electronic device processing and packaging. We took this new graphene material and processed and packaged it using standard manufacturing techniques. We then tested the fully packaged graphene Hall sensors in end-user applications.

### Outcomes

The Hall sensors were used to detect magnetic fields and current levels in specific use cases. This has opened huge avenues for exploitation into the automotive market for graphene devices, and work continues beyond the project to facilitate this.

## Case study:
## Power electronics laboratory

### The opportunity

When CSA Catapult was set up in 2018, the first key market identified was vehicle electrification, with predicted significant growth in demand for power electronics, machines and drives (PEMD) to deliver electrification of the transport sector. Globally, according to market research we commissioned, the estimated power electronics and transport market would reach $18.1 billion by 2023.

Power electronics will help accelerate development of new technology for battery electric vehicles, as they are used to control the flow of power and ensure stability and reliability, allowing for more efficient and effective energy management.

### Our role

To support the UK industry, the Catapult invested in power electronics equipment. Since then, we have developed the capability and know-how to support companies developing power electronics converters.

The Catapult's power electronics laboratory is now one of the UK's most advanced to enable innovation through comprehensive modelling, characterisation, integration and validation facilities for power components, modules and subsystems with higher efficiency and reliability with reduced size, weight and system cost.

Part of the Catapult's investment was in the double pulse test, a standard method in power electronics for silicon, silicon carbide and gallium nitride semiconductors to assess energy loss during device turn-on and turn-off. This test informs power electronics design decisions to optimise reliability, efficiency and thermal management.

### Outcomes

Through investment in and development of CSA Catapult's power electronics equipment and capability:

- **we have supported the creation of supply chains across the UK via the @FutureBEV and ESCAPE projects**
- **this capability has been further exploited by over 20 collaborative research and development projects worth around £62 million, working with a wide range of academia and industry**
- **the companies we have worked with have leveraged public funding of £17.7m since using the power electronics equipment**
- **the companies we worked with showed an average increase in TRL of 4 by the end of our projects**

*"Our power electronics lab provides a unique offering to industry. It accelerates the delivery of next generation power electronics technologies vital for Net Zero. Our unrivalled know-how and domain expertise means we can support industry to get products to market quicker."*

**Nick Singh**

Chief Technology Officer
CSA Catapult



## Case study:
## Siemens Power Electronics Innovation Hub: on our way to an all-electric society

In July 2022, a strategic innovation partnership with Siemens UK led to the establishment of a dedicated hub at CSA Catapult's Innovation Centre.

### The opportunity

In a first for both companies, the strategic collaboration between Siemens UK plc and the Catapult aims to help build the UK's ambition to lead globally in power electronics, machines and drives. The Siemens Power Electronics Innovation Hub represents the combined dedication of both organisations to nurture innovation and champion sustainable tech progress.

The rapidly advancing landscape of power electronics offers a wealth of opportunities to deliver Net Zero through electrification. Located in Newport, there is a strategic hub for connecting with academic institutions, Catapults, RTOs, industry insiders, emerging start-ups and funding organisations.

The partnership with Siemens highlights CSA Catapult's expertise and highlights the untapped potential of the UK's electronics sector.

### Our role

The Catapult's technology centre of excellence is a key intervention for UK industry and provides involvement in the research initiatives and is pivotal in the pursuit of groundbreaking innovations in smart power electronics. By integrating artificial intelligence, the Catapult's power electronics team can develop data models that help solve complex industry demands.

### Outcomes

The strategic partnership is a platform for mutual research and commercial pursuits, focussed on state-of-the-art power electronics, machines and drives. Expected outcomes include enhanced technical proficiencies, skills development and potential new jobs in the UK.

*"Our innovation hub partnership with CSA Catapult is bucking up the trends for electrification, digitalisation and sustainability for the wider UK PEMD sector. Together we are maturing smart power electronics technologies with compound semiconductors through working in ecosystems of SMEs, universities and research technology organisations, as well as creating new full-time jobs and sponsoring students to contribute towards PEMD skills and talent development in the UK."*

**Imran Agha**

Head of Technology & Innovation UK Center of Competence Power Electronics
Siemens

# Translating research



**The UK is a global leader in academic research into semiconductors, according to Clarivate's 2022 list of highly cited researchers, and the UK is third in the world overall with 8% of academic publications. In 2020, a report published by the Department for Business, Energy & Industrial Strategy (BEIS) confirmed that the UK is third in the world for semiconductor publications.**

According to a report published by Beauhurst and the Royal Academy of Engineering in April 2022, in 2020–21 the value of investment secured by university spin-outs increased by 69.3% with a total value of investment secured of £10.9 billion.

The Catapult's technical capabilities in power electronics, radio frequency and microwave, photonics and quantum align naturally with corresponding university specialisms, creating a direct pathway from early-stage academic research to later stage commercialisation.

This relationship facilitates the two-way transfer of ideas, with industry presenting new challenges for future academic research.

## Highlights

- **in 2022–23, we continued to be a trusted partner of both academia and industry, with more than 16 collaborative R&D projects with over 57 partners, including seven leading UK universities**
- **throughout 2022–2023, 12% of all our collaborative projects involved an academic partner**

Case study:

## Working with Cardiff University on research that accelerates commercialisation

### The opportunity

Artificial intelligence (AI) presents the opportunity to create a new and more efficient way of modelling and designing power electronic converters. In a joint study undertaken with Cardiff University, the team explored a new design method using a type of AI known as artificial neural networks (ANN), which uses algorithms and computing systems that mimic the interconnected neural networks of the human brain.

The ANN was trained on an existing dataset of over 2,000 converter designs, so the team were able to select the most appropriate design for their desired efficiency and power density.

The team selected four major components for the ANN-based design, including power gallium nitride (GaN) field-effect transistors (FETs), inductors, capacitors, and heat sinks.

### Our role

Working strategically with academic partners like Cardiff University, CSA Catapult can bridge the gap between research and application development.

The Catapult validated the design approach through experimental tests on a GaN-based single-phase inverter that was created using the specified design.

### Outcomes

- **the new method has reduced design times for technology by up to 78% compared to traditional approaches and was used to create a device with an efficiency of over 98%**
- **the team's findings have been published in the IEEE *Open Journal of Power Electronics* and IEEE *Transactions on Power Electronics***
- **in January 2023, we signed a memorandum of understanding (MoU) with Cardiff University, laying the foundations for a long-term partnership to promote research in areas of common strength and to create a lasting public impact in the UK and beyond. The MoU sets out a framework to develop joint research projects and funding bids, exchange staff, share facilities and equipment, develop teaching initiatives, and create a pipeline of skills and talent**



*"Accurate and fast transient modelling/simulation approaches are essential to efficiently and to rapidly optimise the performance of wide bandgap power electronics systems. We are delighted to work together with CSA Catapult to address this gap."*

**Dr Wenlong Ming**

Co-author of the study
Senior Lecturer Cardiff University
Senior Research Fellow CSA Catapult

*"Automated power electronics design optimisation enables the full exploitation of wide bandgap power semiconductor advantages when compared to their silicon counterparts. We are excited to be working with Cardiff University in this innovative area."*

**Dr Ingo Lüdtke**

Co-author of the study
Head of Power Electronics CSA Catapult
Honorary Visiting Professor Cardiff University

# Innovation



**Innovation in advanced packaging plays an important role in supporting the development and acceleration of compound semiconductor technology.**

The UK has unique strengths in advanced packaging, IP and design, as identified in the BEIS Select Committee inquiry report 'The semiconductor industry in the UK', published in November 2022.

We provided oral and written evidence to the inquiry and emphasised the opportunity for advanced packaging in the UK. The report identified an opportunity for the "development of existing strengths in compound and advanced material semiconductors, to meet demand in emerging markets".

## Case study:
## Thermal management – reducing energy losses in devices

### The opportunity

The development of compound semiconductor applications is fundamental to the effective thermal management of power electronics. It reduces electrical energy losses in devices. This is a complicated process, especially as devices such as power modules reduce in size. Compound semiconductor application package sizes are smaller, which means thermal losses are much smaller and devices more energy efficient, with heat removed from them as quickly as possible.

### Our role

- **novel package architecture and modelling**
- **active/passive cooling**
- **novel assembly, and materials; thermal characterisation**

### Outcomes

Thermal management requires creating good correlation between thermal models and data measurements.

The Catapult developed a digital twin of the process required to define the input data necessary to have good correlation in the thermal design. New capabilities led to a number of collaborative research and development projects.

**Results include:**

- **developing bond line measurements with the process engineering team**
- **developing validation of thermal devices simulation using junction to case thermal resistance and junction temperatures**
- **measuring thermal conductivities of materials such as silicon grease, graphite sheets and silicon wafers; 3D printed materials by a thermtest machine**

# Developing skills to support industry



## Our Skills Academy continues to deliver the Catapult's programme to help build the compound semiconductor workforce for the future.

Working every day with industry and academia reinforces the growing demand for skills in compound semiconductors, while creating awareness of the huge opportunities for young people remains a challenge. Market analysis suggests that the industry's aggregate annual growth could average from 6% to 8% a year up to 2030.

Partnerships are essential to our delivery of skills initiatives. This year we worked in collaboration with UKESF, CS Connected and its member companies, Innovate UK, Driving the Electric Revolution and the Gatsby Foundation.

### Starting young

The Catapult developed three STEM (Science, Technology, Engineering and Maths) outreach initiatives in primary schools. We delivered a partnership with Innovate UK's Driving the Electric Revolution programme in South Wales by a third-party company, Primary Engineer. It is supported by engineers from across the compound semiconductor cluster.

### Secondary school programmes

We have been developing a bespoke programme targeting Year 8 in schools across South Wales.

Aimed at Year 10 and 11 learners, "Spark their imagination, power their future" will be delivered in Wales in 2024 in partnership with the UK Electronic Skills Foundation (UKESF) and it is a significant opportunity to scale up our skills programme.

## Supporting the move into industry

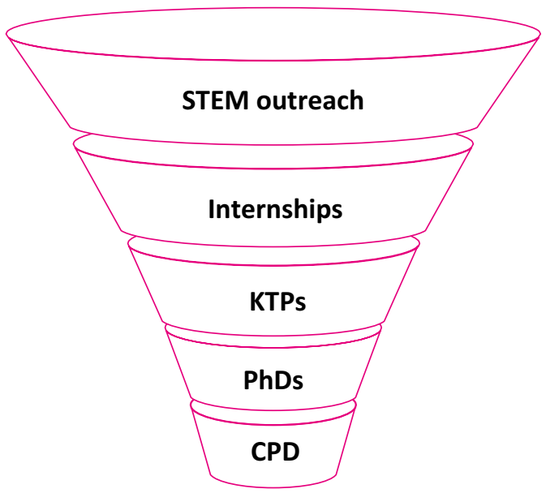
As members of the UKESF Scholarships Scheme, the Catapult supports electronics undergraduates in several ways, including an annual bursary, paid work placements, mentoring and networking opportunities. During summer 2022, five scholars joined the team, each specialising in a specific technology area.

We make the most of the potential these interns have to influence their own next generation while they are with us, and they play a powerful role in our STEM outreach, delivering sessions at events such as Cardiff Science Festival.

## Nurturing transformational expertise

CSA Catapult sponsors PhD student research at the Compound Semiconductor Centre for Doctoral Training (CDT) and the Sustainable Electrical Propulsion CDT.

### Skills programme




## Skills Academy outputs

Driving the development of the skills we need for a thriving compound semiconductor industry is an extremely important part of our role. Skills development is embedded in our day-to-day operations with the involvement of all colleagues, 30% of whom are volunteer STEM ambassadors, and this encourages career pathways in science, technology, engineering and maths.

Our skills development activities during this year spanned all of education, as we:

- **supported five PhD students from across the UK, including two via Centres for Doctoral Training (CDT)**
- **sponsored ten undergraduate interns**
- **hosted over 30 teachers at industry training and engagement visits to the Innovation Centre**
- **engaged with more than 400 families through our electronics outreach programme**
- **provided 65 schools' careers and business engagement advisors with our information and marketing materials**



## Planning for the future

CSA Catapult uses a bespoke, accurate impact assessment method to model future skills needs and develop targeted programmes at every level of education. Over time, this will help us develop system-wide skills forecasting as well as provide evidence of knowledge transfer.

We are involved in a UK-wide programme for skills foresighting, funded by a grant from the Gatsby Foundation, with our involvement covering South Wales.

## Knowledge Transfer Partnerships (KTP)

- **as the first Catapult to be awarded knowledge base status by Innovate UK, we have already identified several KTP candidates to transfer technology in areas including the Internet of Things, human–machine interaction and solar energy harvesting**
- **the Catapult works with the Driving the Electric Revolution Industrialisation Centres (DER-IC) to bring together the University of Bristol, Bath University and the University of West of England (UWE) in the South West of England to provide upskilling and reskilling programmes**
- **the Catapult works with the Careers Transition Programme (CTP) to identify skills that ex-service personnel can bring to the compound semiconductor industry and assess if we can offer 'top-up' programmes to enable a much swifter transition into the industry**

*"Coming for an industrial placement at CSA Catapult was a truly tremendous experience!*

*"Having worked in the power electronics department, I had the privilege of learning a lot from such intelligent individuals who were so passionate about the projects they were working on.*

*"I was able to get hands-on experience and apply the knowledge accumulated at university first hand in real-time projects and develop my understanding and skills. This has been a great stepping stone as I begin my career in this industry and would highly recommend that anyone interested in being at the forefront of innovation apply."*

**Vedant Shah**

UKESF Scholar

# Equality, diversity and inclusion



## Our commitment to diversity and inclusive workplaces in innovation

This year we were pleased to be recognised as a Great Place to Work. The Catapult strives to have an inclusive culture where all employees can flourish. Our values are collaboration, innovation and trust. We want all employees to work in a supportive, fulfilling working environment where everybody feels able to bring their whole selves to work.

We have a very diverse workforce and our employees have a wide range of ages, ethnicities, abilities, faiths, sexual orientations, and parental and caring duties.

CSA Catapult has around 100 employees, with 21 different nationalities, and a third of our people are female. Our Diversity Dashboard illustrates that our "women in STEM" stand at 11% of our workforce, and 30% of our colleagues have identified as BAME.

### Inclusivity in Innovation Charter signed in 2022

Along with other Catapults, we are signatories of the "Inclusivity in Innovation Charter". It sets out a vision for diverse and inclusive workplaces in innovation, and signing it means we have committed to the following:

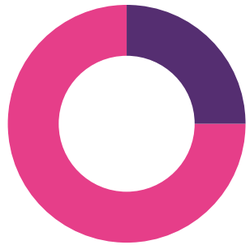
- **we will ensure that ED&I is embedded in our culture and throughout our policies and procedures**
- **we aim to recruit the most talented individuals to our workplace and empower them to realise their goals**
- **we will celebrate the individual as part of a strong and diverse team**
- **we will promote an expectation for our collaborators to uphold ED&I practices**
- **we will share best practices within the network and continually strive to improve**

## CSA Catapult is a committed member of Inclusive Employers

This year we worked towards an award from the Inclusive Employers Standard, which looks at our commitment to equality, diversity and inclusion over the last 18 months. We were pleased to receive a Bronze Award in 2023.



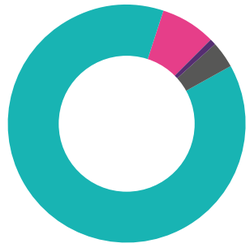
**Male/Female**
Male 72% (68%)
Female 28% (32%)



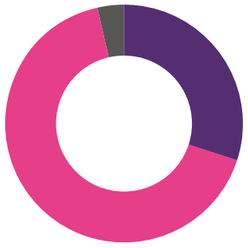
**Women in STEM**
11% (25%)

**Married/Civil partnership**
Yes 40% (39%)
No 51% (46%)
Prefer not to say 9% (15%)

**Disability**
Yes 2% (3.5%)
No 98% (92%)
Prefer not to say 0% (4.5%)



**Sexual orientation**
Bisexual 3% (1%)
Gay man/woman 4% (3.5%)
Heterosexual 86% (88%)
Prefer not to say 7% (7.5%)



**Caring responsibilities**
Yes 25% (30%)
No 66% (66.5%)
Prefer not to say 9% (3.5%)

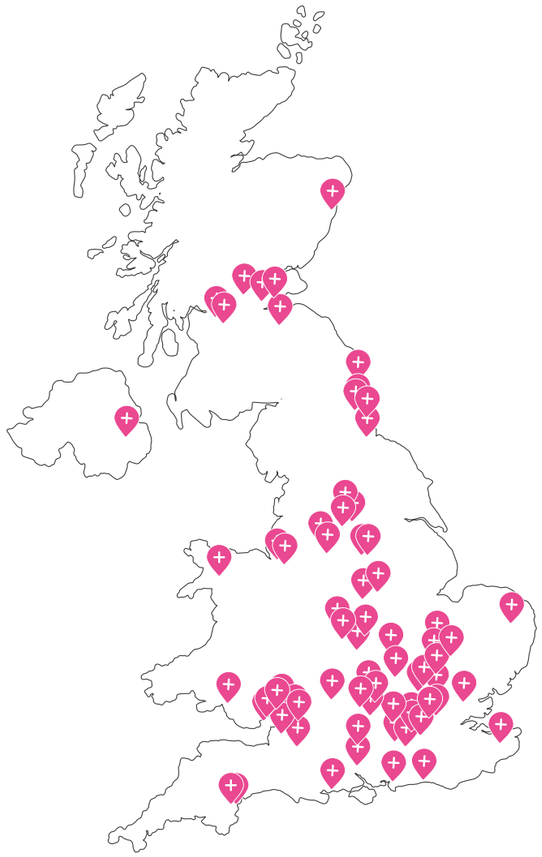
(2021–2022 data in brackets)

# Regional clusters



**Supporting regional clusters to develop and accelerate compound semiconductor applications is a key part of our strategy. We play a key role in the South Wales compound semiconductor cluster, and we are expanding our involvement in clusters across the UK to Bristol, the North East of England and Scotland. We are working with partners in the North East to help grow the existing semiconductor cluster.**

According to our impact analysis, we have worked with 162 companies since 2018 across the UK in the following areas:



| Region | Number of companies worked with |
|---|---|
| East Midlands | 8 |
| East England | 21 |
| London | 23 |
| North East | 10 |
| North West | 5 |
| Northern Ireland | 3 |
| Scotland | 13 |
| South East | 26 |
| South West | 21 |
| Wales | 12 |
| West Midlands | 12 |
| Yorkshire and the Humber | 8 |

# Playing a key role in the South Wales compound semiconductor cluster

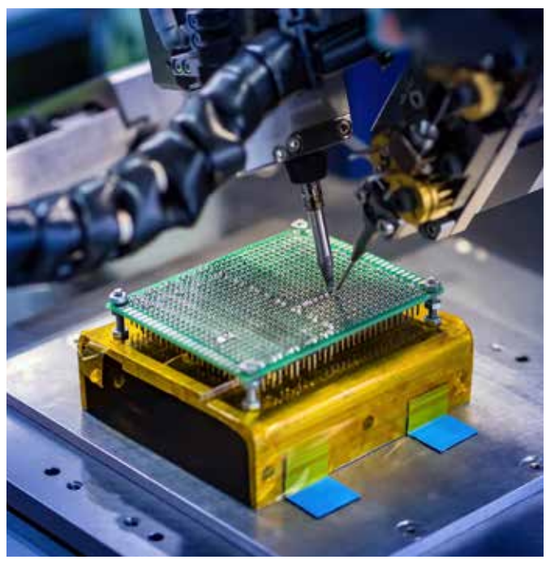
## The opportunity

Clusters are vital to bringing industry and academia together to drive the compound semiconductor industry forward.

CSconnected is the world's first compound semiconductor cluster, with 13 partners, including the Catapult, and is recognised as a world-leading centre of excellence in compound semiconductor research, innovation and manufacturing.

## Our role

As a neutral convener for industry, the Catapult's role is both pivotal and unique: we rapidly build the complex supply chains and deliver vital expertise and infrastructure in evaluation and reliability testing services, some of which are not available anywhere else in the UK.



## Activities

The Catapult contributed to four collaborative research and innovation (CRD) projects part-funded by UKRI's investment of the £25m flagship Strength in Places Fund (2020–25) to further develop South Wales as home to a compound semiconductor powerhouse. The collaborative research programme totals £27.2m.

**The key projects are:**

- **next generation optical communications and sensing. This work package is focussed on the development of optical component solutions for high capacity data centres and LiDAR sensing for autonomous vehicles**
- **large scale GaAs-based wafer manufacturing. This work package is developing scalable compound semiconductor materials solutions for photonic, wireless and flexible photovoltaic applications**
- **novel and efficient compound semiconductor wafer fabrication tools. This work package is advancing next generation semiconductor manufacturing equipment and associated processes to scale up compound semiconductor wafer and device fabrication**
- **advanced processes for 5G and EV systems. This work package will demonstrate novel, advanced volume assembly capability for CS-based electronic modules for 5G applications and power electronics for miniaturised electric vehicle motor drives**



## Outcomes

The objectives of the CRD activity under the Strength in Places Fund are:

- **to generate a pipeline of new IP and increase manufacturing capability in the region**
- **to generate and expand a skilled workforce within the compound semiconductor industry**
- **to develop optimal conditions for sustainable growth of the regional compound semiconductor industry**
- **to seek onward investment to establish a globally recognised cluster for competitive markets**
- **to support the uplift of gross value added (GVA), directly impacted by the growth of the cluster and supply chain expansion within the South Wales region**
- **for CSA Catapult specifically, to support a collaborative consortium in order to co-create, develop and deploy a new generation of technology within the compound semiconductor industry**

Since the inception of the cluster vision, the South Wales compound semiconductor ecosystem has grown to support more than 2,600 high-value jobs, with a more than £300m per annum contribution to the region's economy.

*"Semiconductors represent one of the world's largest and fastest growing industry sectors. Our dependence on semiconductors became abundantly clear during the Covid pandemic when demand for technologies enabled by our sector created severe shortages across many end markets.*

*"Specialising in compound semiconductor technologies, South Wales plays a key role within this essential industry sector that is at the heart of our digital world, from handsets to data centres, mobility and net zero applications, healthcare, robotics and AI."*

**Chris Meadows**

Director
CSconnected

*"The Catapult provides an essential role in connecting the South Wales Semiconductor Cluster to UK supply chains and other centres of manufacturing excellence in the wider UK hi-tech ecosystem. The collective capability is positioned as a key UK sovereign capability, which is a key pillar in the UK National Semiconductor Strategy."*

**Wyn Meredith**

Chair
CSconnected

# International partnerships and projects



**This year we have continued to develop international market and supplier opportunities and highlight the UK's capabilities by building key strategic partnerships with complementary overseas academic, commercial and government organisations.**

We have worked closely with the UK and Welsh governments to play a key role in developing international trade in compound semiconductor applications.

## The opportunity

The Future Telecoms Programme complements a similar programme led by the Catapult to identify bilateral opportunities with India for the electrification of transport.

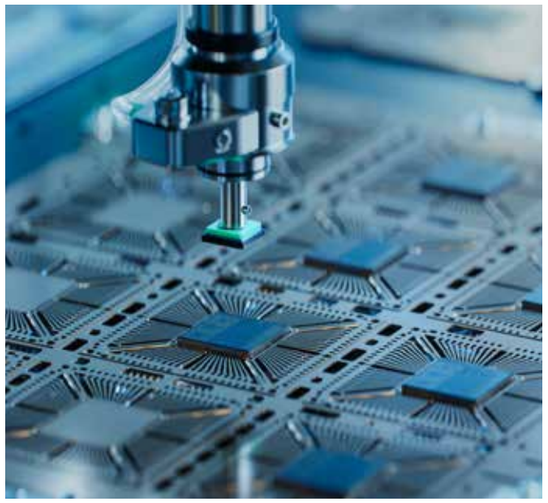
## Our role

In May 2022, the Catapult led a UK delegation of government officials, industry and academia to India, to identify five areas for future collaboration under the programme. In June 2022, we brought a delegation of senior Indian telecoms executives to meet with UK government ministers and industry representatives to cement the plans.

## Outcomes

The Catapult's Future Telecoms Programme provided strong foundations for bilateral collaboration involving key companies and academics from India and the UK and supported the UK government's ambition for an India-UK Free Trade Agreement.

In total, the respective delegations discussed collaboration opportunities with over 180 executives in India and the UK.



# Looking forward



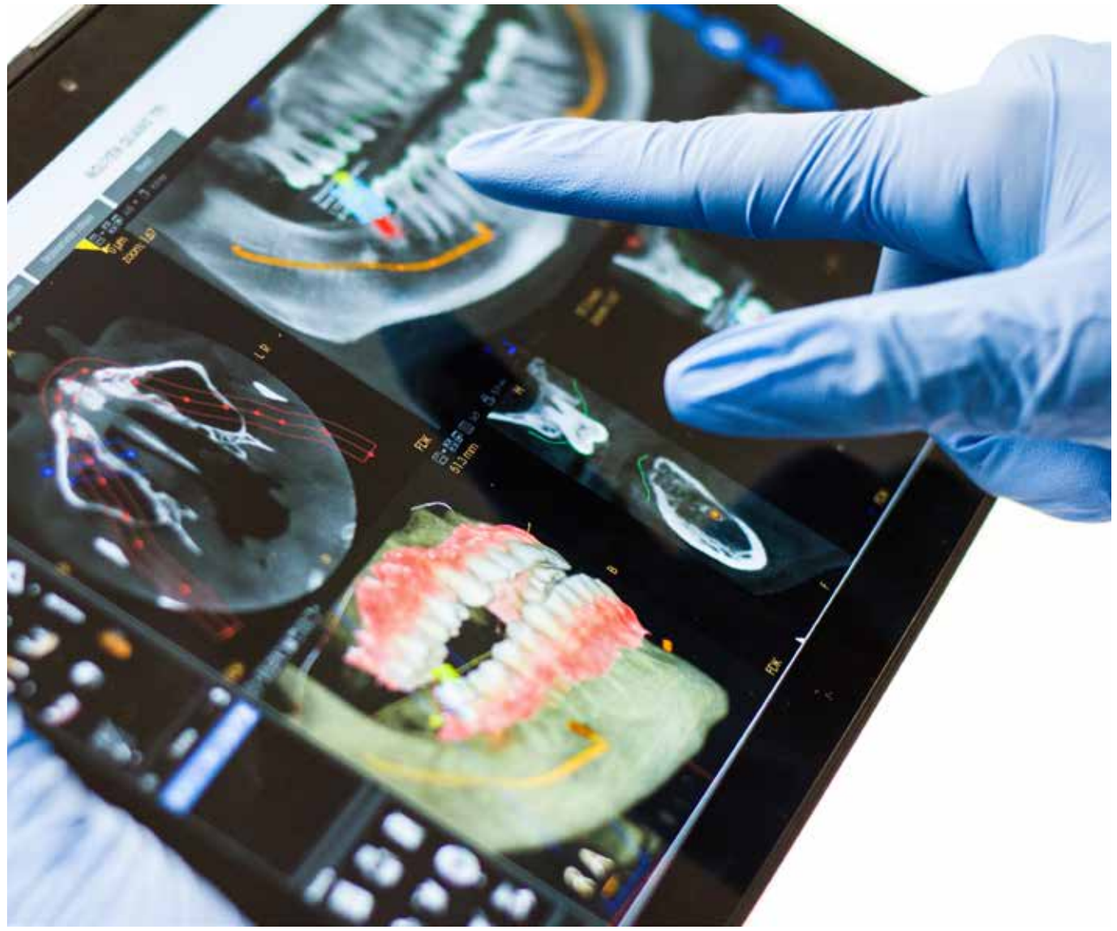
**The demand for more and increasingly powerful and innovative compound semiconductor applications is coming from all directions, all over the world.**

Consumer demand for more devices, limitless data, better energy management and better connection, including 5G and 6G, mean the competitive market for electronics products will grow rapidly in volume and range in the coming years.

New markets will develop in the space, healthcare and quantum sectors as science realises new innovations.

Compound semiconductor technologies are central to meeting all these needs.

Our role is to support the UK's various industries as they look to capitalise on these markets and develop UK sovereignty, by driving the development and commercialisation of compound semiconductor technologies, thereby growing their contribution to the UK economy.



## Our strategy

**Our strategy outlines the steps we will take to achieve our mission and to ensure that CSA Catapult remains financially resilient with funds available to support future investment and opportunities. It has four key areas:**

### 1. Technology Centre of Excellence

**We will continue to become a renowned technology centre of excellence with state-of-the-art equipment and facilities that enables UK companies to develop and test new products. To achieve this, we will also continue to grow and develop our expertise.**

AI will transform how we help industry, with machine learning techniques used to optimise the design and improve the performance of compound semiconductor devices, bringing products to market quicker.

We will help industry de-risk their product development and rapidly explore new ideas and technologies, by continuing to develop demonstrators and evaluation modules for key applications in vehicle electrification and telecoms.

### 2. Supply chains and skills

**Through our continued participation in CR&D and joint industry challenge programmes we will bring industry together to create new supply chains for products and applications that use compound semiconductor technology.**

As well as growing the UK economy, the development of new supply chains will bring new technologies to market, foster innovation and investment, and help level up our communities through the creation of highly skilled and well-paid jobs.

For the UK to become a global leader in developing and commercialising new applications for compound semiconductors, it must also develop the workforce to take the technology forward.

At present, there remains a shortage of young people considering a career in engineering and, consequently, a lack of diverse and well-trained engineers with the necessary skills and experience to enter the compound semiconductor industry.

Our skills strategy outlines how we are helping to develop this pipeline of talent through a dedicated Skills Academy, which is engaging with school students, post-graduates and engineers to demystify the industry and highlight the excellent prospects that are on offer.

We are also undertaking a skills foresighting study to identify the specific requirements needed of future scientists and engineers within specific sectors, such as the telecoms industry.



### 3. Supporting and growing clusters

**Clusters are a major contributor to economic growth and a source of well-paid jobs. They also provide networks, connections, investment and talent that are very difficult to replicate elsewhere and in isolation.**

We will continue to work with regional clusters by setting up a physical presence in key regions where compound semiconductor research, technologies and applications are already prevalent.

We have established a Future Telecoms Hub in Bristol to support the growing number of original equipment manufacturers (OEMs) in the region, and we now also have a presence in Scotland and the North East of England.

We will also develop a front-of-house facility at our Innovation Centre in Newport to support the activities of the compound semiconductor cluster in South Wales.

### 4. Increasing commercial income

**To remain financially resilient and pursue new opportunities to support our mission and purpose, it is imperative that CSA Catapult explores new revenue streams.**

We receive our core funding from Innovate UK as well as competitive grant funding through CR&D programmes with industry.

A third element of our funding comes from direct commercial engagement with companies wishing to use our expertise and capabilities for specific projects. We will focus on developing specific technical and business services that are scalable and have a unique selling point (USP) that attracts a premium from industry. That is where we can add the most value.

Our USP will initially be built on our ability to combine technologies such as power electronics and advanced packaging to deliver compelling solutions that add more functionality into a smaller, lighter device.

We will also develop intellectual property (IP) across existing technologies that can drive commercial growth and provide opportunities to develop spin-out companies.

# Financial highlights



## Income

| For the year ended 31st March: | 2023 £'000s | 2022 £'000s | 2021 £'000s | 2020 £'000s |
|---|---|---|---|---|
| Innovate UK core grant funding | 9,974 | 9,459 | 8,543 | 8,402 |
| Third party grant funding | 3,946 | 3,076 | 1,516 | 482 |
| Industrial income | 456 | 546 | 462 | 241 |
| **Total** | **14,376** | **13,081** | **10,522** | **9,125** |

## Balance sheet

| For the year ended 31st March: | 2023 £'000s | 2022 £'000s | 2021 £'000s | 2020 £'000s |
|---|---|---|---|---|
| Fixed assets | 10,571 | 11,371 | 12,525 | 11,406 |
| Net current assets | 2,373 | 1,186 | 1,060 | 1,105 |
| Creditors | (9,162) | (5,944) | (5,105) | (3,857) |
| Provision for liabilities | (12,414) | (12,433) | (13,553) | (12,504) |
| Net assets | 529 | 124 | 31 | 8 |
| Capital and reserves | 529 | 124 | 31 | 8 |

# CSA CATAPULT

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**Compound Semiconductor Applications (CSA) Catapult**

CATAPULT
Compound Semiconductor Applications

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