TURNING IDEAS INTO REALITY

WITH COMPOUND SEMICONDUCTORS

CATAPULT
Compound Semiconductor Applications

CONTENTS

BRIDGING THE GAP BETWEEN CONCEPT AND IMPLEMENTATION

- CSA Catapult's know-how, tools and services are turbocharging UK companies' innovations in compound semiconductor technology
- Discover a unique set of engineering capabilities for turning a concept into reality

Compound semiconductor devices have the potential to transform the world of technology in the 2020s as radically as the silicon transistor did in the 1960s and 1970s.

In the fields of power electronics and radio frequency systems, compound semiconductor devices can enable product manufacturers to achieve dramatic improvements in performance, size, weight, cost and power. In photonics, compound semiconductors provide unique emitter and detector functions to enhance sensor capability.

Compound semiconductor technology has such potential that it has triggered a cascade of innovative developments at UK companies and research institutes.

But the market for compound semiconductors is so new that the infrastructure, systems and processes for realising a concept in the form of a working prototype or a complete system board have not been readily available to UK companies.

> *It is this challenge which CSA Catapult meets. Our role is to support each customer's realisation of an innovative system or product concept.*

CSA Catapult's expertise in compound semiconductor technology, its tools and its services are in use today by customers in various markets, particularly in:

- Transportation
- Clean energy
- Digital communications
- Security and defence

Forecasts suggest that in the near future, manufacturers of healthcare equipment will also be working with CSA Catapult to take advantage of compound semiconductors.

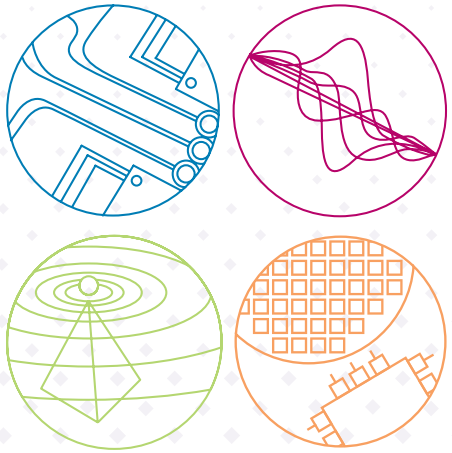
Aligned with the customer's development flow

Customers engage with CSA Catapult to accelerate and optimise the implementation of compound semiconductor-based innovations. The capabilities that CSA Catapult offers mirror the customer's product development flow via its **MCIV – Modelling, Characterisation, Integration, Validation – framework**.

Our capabilities in test engineering, simulation, packaging and layout, and validation enable customers to:

- Accelerate the system design process to shorten time-to-market
- Optimise product functions, features or costs
- Successfully meet design specifications for performance, reliability, lifetime and cost to maximise the chances of commercial success

So whether the goal of your concept is to improve efficiency, reduce system size or weight, cut system cost, or offer new value in performance or features, CSA Catapult's capabilities can help you in the process of turning your idea into a real product which is ready to go to market.



Supporting key markets in the adoption of compound semiconductors

Market	Typical applications for compound semiconductors	How CSA Catapult supports customers
Transportation	Electric and hybrid-electric vehicle motors and chargers Auxiliary electric motors in conventional aircraft Novel electric propulsion technologies for aircraft	Deploying MCIV framework in development of GaN or SiC transistor-based designs Consultancy on power electronics design projects
	RADAR for ADAS and autonomous vehicles	Deploying MCIV framework in development of GaN or GaAs transistor-based designs
	LiDAR for autonomous vehicles	Deploying MCIV framework in development of enhanced laser beam generation and steering systems and enhanced IR sensors Development of LiDAR emitter evaluation modules
Clean energy	Solar power system inverters and micro-inverters Inverters in wind turbines High-efficiency power distribution Power conversion and distribution in emerging renewable generation technologies	Deploying MCIV framework in development of GaN or SiC transistor-based designs Consultancy on power electronics design projects
Digital communications	5G mobile base transmitter stations and micro-cells	Deploying MCIV framework in development of GaN or GaAs transistor-based designs
	Phased arrays at 27.5-31GHz	Development of phased array evaluation modules
Security and defence	Secure microwave satellite communication	Deploying MCIV framework in development of GaN or GaAs transistor-based designs
Healthcare equipment	Gas sensing for advanced diagnostic techniques such as breath measurement Blood glucose monitoring	Deploying MCIV framework in development of advanced imaging devices Development of medical imaging evaluation modules

THE MCIV FRAMEWORK

Services to support you from concept to market-ready product

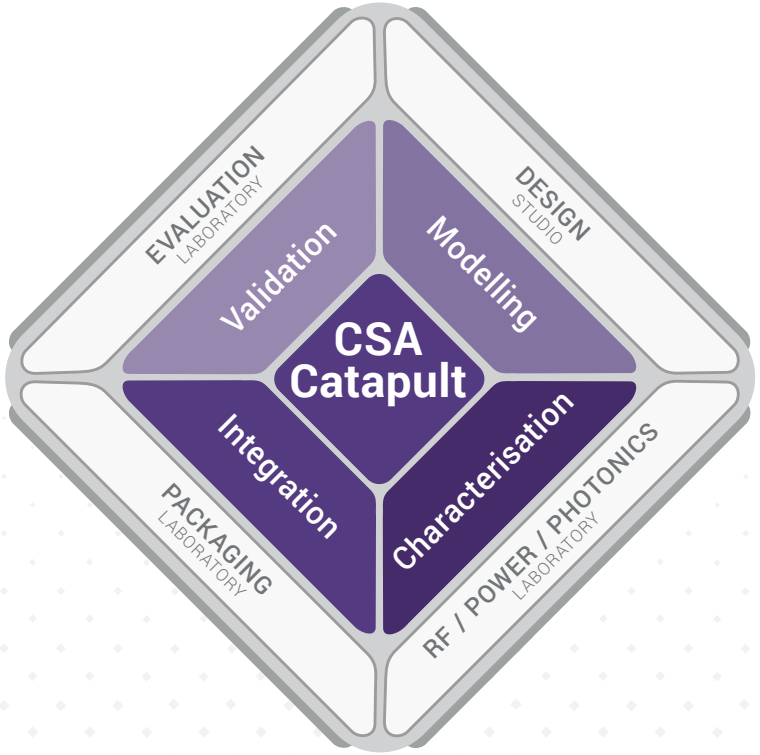
MCIV: Modelling, Characterisation, Integration, Validation

The MCIV framework through which CSA Catapult provides its services to adopters of compound semiconductors mirrors the flow of a design innovation as it is transformed from a raw concept into a market-ready product, in a process known as Virtual Product Development (VPD).

The VPD capabilities of CSA Catapult have been configured to support the flow of commercial, market-or customer-oriented development projects. They can also be integrated into collaborative R&D projects with commercial and academic partners. This is in line with CSA Catapult's remit to support the development of commercial proofs-of-concept, prototypes and products, and to accelerate the release of commercial products to the market.

The MCIV services that CSA Catapult provides help customers to:

- **Optimise** their selection of a compound semiconductor device or module
- **Simulate** accurately the behaviour of a compound semiconductor system in its intended application
- **Refine** the electrical/optical/thermal design of a packaged device, module or system
- **Optimise** the system design to meet targets for lifetime, reliability, cost or any other design parameter



MODELLING

CSA Catapult's engineers use state-of-the-art software tools to build models of a device's, module's or system's behaviour under application conditions. Modelling enables the designer to simulate system performance in software, and to understand the electrical, thermal, mechanical or optical design permutations and trade-offs before committing time or money to building a prototype.

How you benefit from the Modelling service

Hardware development is time-consuming, and every additional iteration of a hardware design adds expense and delays market entry. Accurate modelling informs design decision-making, helping to ensure that hardware designs are right first time.

CHARACTERISATION

Detailed testing of a compound semiconductor device or module provides developers with accurate measurements of a device's electrical/optical, thermal and mechanical behaviour. Data provided by CSA Catapult's characterisation service goes far beyond the limited information provided in datasheets supplied by device manufacturers.

How you benefit from the Characterisation service

Detailed, application-specific device characterisations eliminate the guesswork involved in prototype development, and reduce the number of hardware iterations before a design is finalised. This leads to steep falls in development time and dramatically accelerated time-to-market.

INTEGRATION

Typically operating at very high frequency, high temperature and/or high power, the package or supported device in which a compound semiconductor is embedded is subject to extreme thermal, electrical and mechanical stresses. CSA Catapult supports integration of compound semiconductors through the provision of the packaging expertise of experienced engineers, and through access to and support in using advanced software design tools for thermal and EMC design.

CSA Catapult's packaging laboratory also builds modules or system boards in prototype quantities.

How you benefit from the Integration service

Design and build optimisation performed by CSA Catapult results in products which are more reliable, have a longer lifetime, gain compliance with EMC and other regulations more quickly, and are easier to integrate with a system's other electrical or optical systems.

VALIDATION

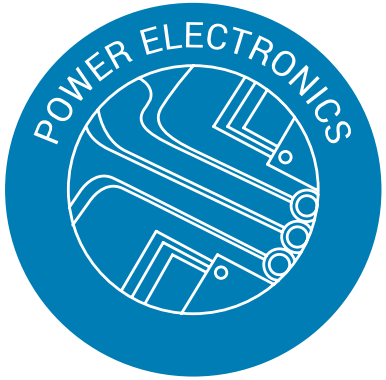
CSA Catapult's specialist laboratories perform accelerated lifetime tests, vibration tests, high-temperature tests, power cycling tests and other test routines to verify the system's performance against its specification. Our expert test engineers use state-of-the-art equipment to provide the widest possible test coverage and the most accurate test results.

How you benefit from the Validation service

Custom validation testing provides the greatest possible confidence that the product or system will perform as specified when operated in real-world conditions.

MCIV SERVICES IN POWER ELECTRONICS

Designing for high efficiency, high power and high temperature



Two compound semiconductor materials – gallium nitride, and silicon carbide – are already enabling developers of power electronics systems to realise more efficient converter topologies, and operate switch-mode power supplies at higher temperatures and at much higher frequencies. The power, size, weight and cost improvements that can be gained offer new scope to gain competitive advantage in markets such as:

- Clean energy
- Automotive
- Aerospace
- Industry
- Data centres

If breakthroughs in power-system performance are to be made by UK companies, they will need to test the limits of the electrical, thermal and mechanical envelopes within which compound semiconductor-based power circuits operate.

And the suite of MCIV services provided by CSA Catapult's Power Electronics laboratories is the country's **most advanced and comprehensive development, test and validation facility** for power electronics pioneers.

DESIGN STUDIO

modelling of compound semiconductor devices and modules

The Design Studio gives customers access to the industry's most advanced and sophisticated software development tools for modelling the thermal and electrical behaviour of GaN or SiC devices, and to development engineers with world-class expertise in their use.

Modelling tools available for users of the Design Studio include **Matlab Simulink, EMPro, SolidWorks, and PSpice**.

By modelling parameters such as response to transient voltage events, parasitic inductances and capacitances, and the spread and intensity of hot-spots, CSA Catapult enables power system designers to make informed decisions about architectures, devices and operating limits before making costly commitments to hardware development.

POWER LAB

accurate and detailed characterisation

CSA Catapult's Power Lab contains a unique combination of high-performance power and thermal analysis instruments. It provides customers with more detailed and accurate measurements of actual device, module or board-level behaviour than can be acquired anywhere in the UK.

The suite of instruments operating in the Power Lab ranges from **device power analysers, system power testers and impedance analysers to an automated wafer probe, an advanced temperature source and thermal cycling tester.**

This suite of instruments enables CSA Catapult to provide customers with detailed data about the behaviour of an off-the-shelf transistor or other device, or of a custom module or system, under a range of operating conditions that the customer specifies.

PACKAGING LAB

hardware integration optimised for thermal, electrical and mechanical behaviour

The Design Studio and Power Lab help customers to choose the right device and develop their power circuit with confidence.

In CSA Catapult's Packaging Lab, hardware design engineers optimise the integration of components such as transistors, gate drivers, capacitors and current sensors into a complete, designed-for-manufacturing package. The lab also produces sample units for testing and prototyping purposes.

By drawing on CSA Catapult's reservoir of skills and expertise in device integration, customers can benefit from a hardware implementation which meets the application's specifications for EMC, temperature thresholds, and reliability and lifetime, while optimising as required for size, weight, power and/or cost.

EVALUATION LAB

validating real-world performance

At the end of the design and integration process, the customer has a hardware product in modular or system form. Does it perform to specification? And does its measured lifetime meet the application's requirement?

These are questions that CSA Catapult can answer by performing validation tests in its state-of-the-art Evaluation Lab.

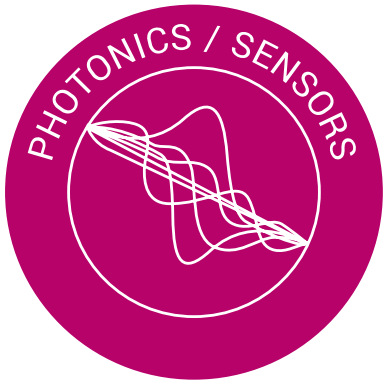
Equipment in the lab includes scanning acoustic microscopy and tomography instruments, internal physical inspection equipment, thermal shock testers, vibration testers, accelerated lifetime testers, and power cycling testers operating at up to 300kVA.

The Evaluation Lab can generate comprehensive reports on thermal resistance, environmental and lifetime tests, failure analyses, insulation tests and mechanical data.

There is no more comprehensive suite of resources in the UK for validating whether a compound semiconductor-based system is ready for release to an end user.

MCIV SERVICES IN PHOTONICS

Supporting customers' breakthroughs in optical sensitivity and beam control



Manufacturers of optical ranging, measurement, communications and detection equipment have long experience with various types of compound semiconductor device.

Demand in fast-growing application domains such as transportation, medical diagnostics and quantum computing, however, is driving a new wave of product development which stretches the limits of existing devices' performance. Photonics engineers are now striving to meet the extreme performance requirements of systems such as LiDAR ranging sensors in autonomous vehicles or surgical robots, or of new tunable laser sources for use in medical diagnostics and Optical Coherence Technology (OCT).

These leading-edge system development projects can all benefit from the suite of MCIV services and laboratory facilities that CSA Catapult provides for the evaluation and testing of advanced laser source and sensor systems.

DESIGN STUDIO

modelling of laser source and photodetector systems

The Photonics Design Studio contains a suite of optical, thermal, structural and electromagnetic simulation tools to enable customers to refine their design in software before committing to a hardware design.

Modelling tools available for users of the Design Studio include **Zemax for optical modelling, SolidWorks** for mechanical design and **Comsol for thermal design**. The Design Studio also supports the simulation of the electrical parts of optoelectronics system designs, with tools such as **EMPro for electromagnetic simulation**, and **SystemVue for system-level design**.

Development of advanced LiDAR systems is also supported by the provision of hardware Evaluation Modules (EVMs), which provide a design blueprint and device evaluation platform for developers of:

- LiDAR detectors
- Swept-source lasers

PHOTONICS LAB

accurate and detailed optical characterisation

The Photonics Lab's test station provides a comprehensive set of options for characterising and evaluating new laser source and emitter technologies. This supports product development and supplier quality assessment.

The suite of instruments for characterisation of optical sources ranges from **optical spectrum analysers and beam profiling instruments** to **electrical power analysers** and **thermal analysers**.

This suite of instruments enables CSA Catapult to provide customers with detailed data about the optical, electrical and thermal behaviour of a die, chip-on-submount, package or system. The equipment can be used for the characterisation of laser- or LED-based systems.

The Photonics Lab also performs detailed characterisation of optical sensors, measuring dark signal, noise, saturation, dynamic range and linearity.

PACKAGING LAB

hardware integration optimised for optical behaviour

The more extreme demands made of photonics systems in applications such as ADAS and surgical robots give rise to greater thermal, mechanical and electrical stresses in source and sensor assemblies.

The Packaging Lab at CSA Catapult brings decades of specialist expertise in system integration to bear on the cutting-edge product developments under way in markets such as automotive, medical diagnostics and defence equipment.

It can perform integration of a laser or LED source or of a detector, in a package, module or board-level system, while optimising at the customer's request for size, performance or cost. The lab can produce sample quantities for prototyping or test purposes.

EVALUATION LAB

validating real-world performance

CSA Catapult's Evaluation Lab validates whether source or detector modules or systems are ready for operation in application conditions. Harsh and accelerated test equipment assures the developer of the device's lifetime, reliability, and tolerance of extremes of temperature, mechanical stress and electromagnetic interference.

State-of-the-art equipment available to users of CSA Catapult's Evaluation Lab includes a combined climatic chamber and shock and vibration tester, an accelerated (high temperature) lifetime tester for optical components in chip or package format, and advanced microscopy and spectroscopy equipment for detailed failure analysis.

MCIV SERVICES IN RF AND MICROWAVE

Supporting customers at the leading edge in automotive, digital communications and aerospace/defence

Development at the leading edge of RF and microwave technologies is backed by more investment and resource than ever before, as users in the fields of communications, transportation, aerospace and defence equipment look for new ways to perform functions such as:

- More accurate ranging over longer distances
- Faster data transfer
- Support of dense networks containing thousands of wireless sensors

The ultra-high frequency operation enabled by the use of compound semiconductor materials such as gallium nitride and silicon germanium is driving manufacturers to explore the use of new devices, new architectures and new packaging techniques.

At this leading edge of development, CSA Catapult's RF/microwave lab provides the MCIV services to accelerate development and optimise system designs.

DESIGN STUDIO

modelling of RF/microwave devices

The RF/Microwave Design Studio works with customers to develop accurate models of the electrical, thermal and electromagnetic behaviour of a device, package or module. The opportunity to explore in software the unusual range of behaviours of devices which operate at frequencies above 5GHz is valuable, as it dramatically reduces the risk of unexpected system behaviour in hardware design implementations.

Modelling tools available for users of the RF/Microwave Design Studio include Keysight ADS, AWR Microwave Office, COMSOL Multiphysics, SolidWorks and the Altium PCB design suite.

Development of advanced RF and microwave systems is also supported by the provision of hardware Evaluation Modules (EVMs), which provide a design blueprint and device evaluation platform for developers of:

- 5G phased arrays
- Thermal management systems for ultra-high frequency GaN transistors

RF AND MICROWAVE LAB

accurate and detailed device characterisation

The RF and Microwave Lab's test station performs high-bandwidth transmitter and receiver characterisation for component and sub-module evaluation, compliance testing and development.

The equipment available for use in characterisation of RF and microwave devices includes a real-time oscilloscope, an arbitrary waveform generator and a vector network analyser.

Test routines performed by the lab include:

- Semi-automatic on-wafer measurements
- High-power connectorized measurements
- High-power pulsed IV testing
- S-parameter testing
- Non-linear characterisation and load pull at up to 40GHz
- Wideband generation and analysis at up to 40GHz

PACKAGING LAB

combating the physical effects of millimetre wave artefacts

At multi-GHz frequencies, compound semiconductor devices are transmitting and receiving millimetre-wave signals. And at these short wavelengths, the package in which a device or module is housed has the potential to create cavities and generate resonances which can seriously impair system performance.

The RF/microwave design experts at CSA Catapult's Packaging Lab take a system-level view of performance optimisation, and then apply their specialist knowledge to maximise sensitivity, output power and other operating parameters, shaping the package to minimise the amplitude of self-generated interference.

The integration service provided by the Packaging Lab takes care of every aspect of packaging design, including:

- Wire bonding (including ribbon)
- Epoxy die attach
- Flip chip

EVALUATION LAB

validating real-world performance

CSA Catapult's Evaluation Lab helps customers ready a leading-edge RF/microwave system design for production. The validation procedures performed on the state-of-the-art equipment in the Evaluation Lab enable users to verify system lifetime, reliability and tolerance of harsh conditions, and support detailed failure analysis.

Validation tests provided by the RF/microwave Evaluation Lab include:

- RF burn in
- RF life test
- Vibration testing
- Thermal cycling
- Humidity testing
- Electromagnetic compliance testing

PACKAGING INNOVATION

Packaging Lab develops technologies, materials and designs for tomorrow's demanding applications

Industry estimates suggest that some 80% of the cost of a typical compound semiconductor product is in its packaging. At the same time, the package in which a device or module is housed has a profound effect on its value to the end user. An effective package design will:

- Maintain a device's operation in parameters such as temperature and radiated emissions within a specified envelope
- Provide protection from environmental stresses such as vibration, EMI, humidity and contamination, and support reliable operation over a long lifetime
- Minimise cost and enable efficient production in high volume

The demanding applications for compound semiconductors make it unusually difficult for packaging engineers to realise these benefits. Typically they operate at very high frequency and temperature. Automotive, military and aerospace applications might also be exposed to extreme environmental stresses.

CSA Catapult's Packaging Lab has the **specialist engineering expertise, equipment and portfolio of services** to help customers develop packaging designs which are:

- Reliable in the intended operating conditions
- High-performance
- Cost-optimised
- Production-ready

The lab offers cross-disciplinary expertise: it includes specialist thermal, electrical, mechanical and optical engineers dedicated to design, test or assembly.

THREE STREAMS OF SERVICE

To meet customers' requirements for packaging designs deployed in demanding applications, the CSA Catapult Packaging Lab provides three categories of service.

ARCHITECTURAL INNOVATION

Drawing on state-of-the-art thermal and mechanical simulation software, packaging system architects develop novel structures, pin/lead configurations, and bonding methods to meet customers' application-specific requirements.

Design innovations may be validated in the lab for thermal, electrical, optical and mechanical performance and reliability.

LEADING-EDGE PACKAGING R&D

The packaging materials, production processes and development models which are adequate for today's systems might not meet future demand for improved performance and higher tolerance of environmental conditions. Cost constraints will also remain an ever-present factor affecting product designs.

CSA Catapult's vision is to lead the compound semiconductor industry's innovations in packaging materials, development tools and production processes to meet the demands of tomorrow.

The Packaging Lab will also be at the forefront of moves to standardise compound semiconductor packaging, and to develop thermal and mechanical models for standard packages, helping to lower costs and accelerate design implementation.

ADVANCED ASSEMBLY PROCESSES

CSA Catapult's Packaging Lab deploys cutting-edge equipment and techniques in assembling customers' prototypes.

By using the lab's assembly facilities, customers can verify a design, anywhere from proof-of-concept stage up to a final production unit.

Capabilities of the prototype assembly service include:

- Die attach
- Wire bonding
- 3D chip stacking
- Wafer-level packaging
- Solder bumping
- Micro-bumping
- 3D printing

ADDITIONAL SERVICES

- Evaluation Modules (Evm)
- Market Intelligence
- Skills & Training
- Project Management
- Bid Writing

Tel: 01633 373121

Email: info@csa.catapult.org.uk

Twitter: @CSACatapult

Website: www.csa.catapult.org.uk

Linkedin: linkedin.com/company/csacatapult

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