Centre for Additive Manufacturing (CfAM) Biennial Report

May 2021 – April 2023
With the winding down of the coronavirus pandemic, many actors in industry and public life expected a period of recovery, stability and, above all, predictability. In the introduction to our last Biennial Report in 2021, we anticipated that this period of relative calm would be used to decisively address the looming environmental crisis, the effects of which are inching ever closer to everyday life in the United Kingdom. This is reflected in the priorities of our funders at UKRI and EPSRC who have formulated research agendas targeting net zero carbon emissions and more circular ways of organising industrial processes.

With the return of large-scale military conflict to eastern Europe, however, the world has been shaken again in early 2022. These most unwelcome events continue to impact global markets and supply chains and reach into everyday life in the UK. In the manufacturing domain, they have re-emphasised the need for resilient supply chains and adaptable manufacturing systems. In some ways, the war in Ukraine has added momentum to developments already in motion in manufacturing, such as the "reshoring" of manufacturing activities and the adoption of information technology to increase the capability and adaptability of manufacturing processes.

As prominent members of the international Additive Manufacturing (AM) community, we are keenly aware that AM technology will have a pivotal role to play in meeting these challenges. Our track record underlines that CfAM has traditionally placed an emphasis on interlinking complementary strands of research, such as the formulation and selection of highly novel materials, new approaches to material deposition, and digitally enabled design techniques. Given the current global challenges we think that our approach is timelier than ever.
Additive manufacturing in a changing world

Manufacturing finds itself at a crossroads. Having emerged from the global coronavirus pandemic, the war in Eastern Europe has plunged industry into new political and economic disruption. In this section, we briefly summarise our view on the current situation and the likely impacts on research into AM technology in general and on the activities of CfAM in particular. A decades-long era of global stability appears to be ending. This order promoted, among other things, the formation of global supply chains, the mass movement of ideas and knowledge, and a general feeling that international cooperation would ensure a reliable, rules-based order of things. As the coronavirus pandemic and the subsequent invasion of Ukraine have shown, this should not be taken for granted. In their search for political and economic disruption. In this section, we will support manufacturing’s transition towards more sustainable and adaptable processes.

As active members of the global AM research community, we see a pivotal role for AM in producing such change, in turn supporting manufacturing’s transition towards more sustainable and adaptable processes. Specifically, we think that AM has the potential to decarbonise supply chains through the digitalisation of many processes, to enable the introduction of circular lifecycle patterns for many products through its inherent flexibility and openness, and to realise novel and more environmentally benign products through advances in environmentally benign AM, including the discovery of new organic materials, raw materials for the in-situ creation of functional materials for advanced electronics, and innovative glass materials. See, for example, our work towards establishing Overall Equipment Effectiveness (OEE) metrics for AM (p.27). To meet this challenge, local and regional manufacturing businesses, universities, and research and technology organizations (RTOs) must collaborate more closely than ever before. As a leading academic AM research group, we have a special responsibility and must be measured against the impact we have in our own sector. The figure below summarises how the research activities at CfAM relate to significant macroenvironmental factors and shows how our activities propel AM towards creating next generation products with unprecedented levels of functionality and environmental performance.

1. Development of new processes, with an emphasis on multi-material systems that allow the deposition of multifunctional structures, supported by robust digital models. This will unlock unprecedented degrees of functionality and product efficiency. See, for example, our work towards reactive fusion (p.16).

2. Creating a palette of novel materials suitable for scalable and environmentally benign AM, including the development of new organic materials, raw materials for the in-situ creation of high-performance polymers, new metallic alloys for structural and functional use, low-dimensional functional materials for advanced electronics, and innovative glass materials. See, for example, our work towards dialling up materials formulations (p.13).

3. Developing new applications for AM to address critical challenges and to respond to social and demographic factors, including new focus on regenerative medicine and innovative clinical practice, and the cost-effective production of complex, personalised medication. See, for example, our work towards adopting AI for the design of novel lattice structures (p.17).

4. Developing new applications for AM to address critical challenges and to respond to social and demographic factors, including new focus on regenerative medicine and innovative clinical practice, and the cost-effective production of complex, personalised medication. See, for example, our work towards adopting AI for the design of novel lattice structures (p.17).

5. Establishing new operational and supply chain processes to enable resilient, transparent, and agile AM operations. This includes raw material handling and diversification, inventory strategies, and quality control methods. See, for example, our work towards establishing Overall Equipment Effectiveness (OEE) metrics for AM (p.27).

As researchers in this field, we think that sooner, rather than later, there will be increased pressure to develop coherent and general digitalisation strategies, most likely involving novel digital approaches such as artificial intelligence and quantum computing. This will support manufacturing’s transition towards more sustainable and adaptable processes.}

**Diagram:**

1. AM processes supported by digital models
2. New materials for scalable and sustainable AM
3. Application mechanisms linking AM to social and demographic factors
4. New design systems
5. New operational and supply chain processes

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316L/CuSn10 test specimen created using the Aerosint dual material recoater.
Key research areas at CfAM:

- Development of design systems and software tools for both single material and multifunctional AM
- Generating robust digital models of AM
- Discovering organic materials for scalable processes
- Development of new metallic alloys for structural and functional use
- Reactive jetting of high-performance polymers
- Multimaterial jetting of functionalised nano-particulate inks and dielectric materials
- Drop-on-demand jetting of high-temperature metals
- Micro- and nano-scale multimaterial AM and supporting analysis methods
- Next generation biomaterials
- AM of innovative solid dosage forms for pharmaceutical applications
- AM of low-dimensional functional materials for advanced electronics
- New operations management techniques for AM implementation
- Translating AM innovation into effective clinical solutions
- Production of complex glass structures via AM
- Development of polymer nanocomposites for powder bed fusion technologies
- Funding success in multiple large grants, including the EPSRC Programme Grant “Dialling up Performance for on Demand Manufacturing” and The EPSRC Network “Next Generation Rehabilitation Technologies”.
- Opened the Additive Biofabrication Laboratory within the Biodiscovery Institute at the University of Nottingham.
- Established an AM laboratory in Clinical Engineering at Queen’s Medical Centre (QMC), in a joint venture with Nottingham University Hospitals NHS Trust.
- Major reconfiguration of our main laboratory in the Advanced Manufacturing Building.
- Successfully resumed the Additive International conference in 2022 in Nottingham with a line-up of world-renowned experts from across industry and academia.
- Welcomed new staff, including Ginny Birney, Dr Negar Gilani, Dr Helena Henke, Keyvan Jodeiri, Dr Sathish Pandiyar, Dr Luke Parry, Flavia Villarroel, Dr Simeng Wang, Dr Leijian Yu, and Dr Atabak Ghanzi Zadeh.
- Contributions to the Royal Society Summer Science Exhibitions in 2021 and 2023, providing an outlook on highly novel applications of AM.

Centre highlights

- Funding success in multiple large grants, including the EPSRC Programme Grant “Dialling up Performance for on Demand Manufacturing” and The EPSRC Network “Next Generation Rehabilitation Technologies”.
- Opened the Additive Biofabrication Laboratory within the Biodiscovery Institute at the University of Nottingham.
- Established an AM laboratory in Clinical Engineering at Queen’s Medical Centre (QMC), in a joint venture with Nottingham University Hospitals NHS Trust.
- Major reconfiguration of our main laboratory in the Advanced Manufacturing Building.

Additive Manufacturing will have a pivotal role in shifting manufacturing towards sustainability and resilience. As a leading AM research group, we must be measured by our role in this shift.
Key individuals

**Academics**

- **Professor Ian Ashcroft**
  Professor of Mechanics of Solids, Faculty of Engineering, University of Nottingham

- **Professor Derek Irvine**
  Professor of Materials Chemistry, Faculty of Engineering, University of Nottingham

- **Professor Ruth Goodridge**
  Professor of Additive Manufacturing, Faculty of Engineering, University of Nottingham and Biomedical Engineer, Nottingham University Hospitals NHS Trust

- **Professor Chris Tuck**
  Professor of Materials Engineering, Director of the EPSRC Centre for Doctoral Training in Additive Manufacturing and 3D Printing, Faculty of Engineering, University of Nottingham

- **Professor Martin Baumers**
  Associate Professor, Faculty of Engineering, University of Nottingham

- **Professor Marco Simonelli**
  Assistant Professor, Faculty of Engineering, University of Nottingham

- **Professor Richard Hague**
  Professor of Additive Manufacturing, Director of the Centre for Additive Manufacturing, Faculty of Engineering, University of Nottingham

- **Professor Dr Lyudmila Turyanska**
  Associate Professor, Faculty of Engineering, University of Nottingham

- **Professor Dr Yinfeng He**
  Assistant Professor, Seconded to the University of Nottingham in Nanog, China, Faculty of Engineering, University of Nottingham

- **Dr Ian Maskery**
  Assistant Professor, Faculty of Engineering, University of Nottingham

- **Dr Luke Parry**
  Assistant Professor, Faculty of Engineering, University of Nottingham

- **Dr Dr Marco Simonelli**
  Assistant Professor, Faculty of Engineering, University of Nottingham

**Research fellows**

- **Dr Simon Attwood**
  Research Fellow, Faculty of Engineering, University of Nottingham

- **Dr Anil Bastola**
  Research Fellow, Faculty of Engineering, University of Nottingham

- **Dr Valentina Cuzzucoli**
  Research Fellow, Faculty of Engineering, University of Nottingham

- **Dr Najar Gilani**
  Research Fellow, Faculty of Engineering, University of Nottingham

- **Dr Helena Henke**
  Research Fellow, Faculty of Engineering, University of Nottingham

- **Dr Jisun Im**
  Research Fellow, Faculty of Engineering, University of Nottingham

- **Dr Damien Leech**
  Research Fellow, Faculty of Engineering, University of Nottingham

- **Dr Anna Lion**
  Research Fellow, Faculty of Engineering, University of Nottingham

- **Dr Sathish Pandian**
  Research Fellow, Faculty of Engineering, University of Nottingham

- **Dr Adja Touré**
  Research Fellow, Faculty of Engineering, University of Nottingham

- **Dr Feiran Wang**
  Research Fellow, Faculty of Engineering, University of Nottingham

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- **Dr Leijian Yu**
  Research Fellow, Faculty of Engineering, University of Nottingham

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  Research Fellow, Faculty of Engineering, University of Nottingham

- **Dr Atibak Ghanizadeh**
  Research Fellow, School of Life Sciences, University of Nottingham

- **Dr Peng Zhao**
  Research Fellow, Faculty of Engineering, University of Nottingham

- **Dr Dr Peng Zhao**
  Research Fellow, Faculty of Engineering, University of Nottingham

- **Dr Keyvan Jodeiri**
  Research Associate, Faculty of Engineering, University of Nottingham

- **Dr Alekandra Foerster**
  Research Fellow, Faculty of Engineering, University of Nottingham

- **Dr Geoffrey Rivers**
  Research Fellow, Faculty of Engineering, University of Nottingham

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  Research Fellow, Faculty of Engineering, University of Nottingham

- **Dr Robyn Worsley**
  Research Fellow, Faculty of Engineering, University of Nottingham

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- **Dr Keyvan Jodeiri**
  Research Associate, Faculty of Engineering, University of Nottingham
Key individuals

Support staff

- Dr Helena Henke, Dr Anna Lion, Dr Simeng Wang and Dr Leijian Yu, who have joined CfAM as Research Fellows
- Ginny Birney, who has joined us as Research Network Manager for the EPSRC Network in Rehabilitation Technologies
- Flavia Villarroel, who has joined us as Research Manager for the Enabling Next Generation Additive Manufacturing Programme Grant

We congratulate the following members of staff who have been successful with a promotion or commenced a permanent academic position:

- Dr Lyudmila Turyanska and Dr Martin Baumers, who have been promoted to Associate Professor
- Dr Ian Maskery and Dr Marco Simonelli, who have commenced their permanent academic positions as Assistant Professors after completing their Nottingham Research Fellowships
- Dr Luke Perry, who has been promoted to Assistant Professor
- Dr Negar Gilani for securing a position as Research Fellow
- Keyvan Jodeiri for securing a position as Research Associate

The following members of staff have left CfAM. We thank them for their hard work and wish them all the best for their new positions:

- Dr Laura Ruiz-Cantu, Dr Harinee Selvadurai, Dr Cordula Hege, and Dr Gustavo Ferraz Trindade

Additionally, Dr Yinfeng He has been seconded to the University of Nottingham in Ningbo, China, where he is investigating innovations for AM materials and equipment (funded by the China Beacon Institute).

Staff updates since April 2021

We are welcoming the following new members of staff who have joined CfAM:

- Dr Helena Henke, Dr Anna Lion, Dr Simeng Wang and Dr Leijian Yu, who have joined CfAM as Research Fellows
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Major grant successes

**Dialling up performance for on demand manufacturing – programme grant**

Principal investigator: Prof Ricky Wildman
Co-investigators: Prof Felicity Rose (Nottingham), Prof George Malliaras (Cambridge), Prof Clive Roberts (Nottingham), Prof Richard Hague (Nottingham), Dr Anca Pordea (Nottingham), Prof Blair Johnston (Strathclyde), Prof Wayne Hayes (Reading), Prof Richard M. Owers (Cambridge), Prof Anna Croft (Cambridge), Dr Yinfeng He (Nottingham/Beijing), Prof Morgan Alexander (Nottingham), Prof Cameron Alexander (Nottingham), Prof Derek Irvine (Nottingham), Prof Alastair Florence (Strathclyde), Prof Ian Axford (Nottingham), Prof Chris Tuck (Nottingham), Dr Lyudmila Turyansk (Nottingham).

This EPSRC-funded programme (EP/W017032/1, started October 2022) has the ambitious goal of realising highly functional, smart products with the potential to transform key UK industries, including (bio)pharma, cell therapy, regenerative medicine, and (bio)catalysis. Its guiding vision is to create a deployable toolkit and workflow for the rapid formulation of 3D printable materials with automated selection and dial up of bespoke properties. Industry across multiple sectors has identified that whilst it needs personalised/tailored devices, the required materials are not available. Moreover, product development forms an arduous process and the route to market is long. This project will address this challenge by creating a toolkit platform by which industry can deliver, on demand, the materials, and processes necessary for functional products.

The programme grant is executed through four interlinked research challenges (RCs):

- **RC1: Smart product creation**
- **RC2: Materials development**
- **RC3: Design systems development**
- **RC4: Process integration**

For more information, and for a full list of academic and industrial partners, please visit the programme website:
This EPSRC-funded network (EP/W000679/1, started January 2022) focuses on developing the next generation of advanced technologies for rehabilitation, targeting musculoskeletal, cardiorespiratory, neurological, and mental health conditions. It is connected to the new £70m National Rehabilitation Centre (NRC), a major national investment in patient care, innovation and technology, due to open to patients in 2024.

This multidisciplinary network brings together a range of stakeholders, including academic researchers, technicians, healthcare practitioners, patient representatives, and industry. It consists of a core membership of clinical and technical experts from the rehabilitation field, alongside patient representatives sharing their lived experience of conditions and rehabilitation. The network introduces researchers who are not typically involved in rehabilitation research, but who have potentially transformative technologies and materials, into the rehabilitation technology community.

Following a series of “Grand Challenge Workshops”, the network will fund feasibility research in support of new interdisciplinary collaborations to the value of £400,000.

The following matrix summarises the clinical and technological focus areas of the network:

<table>
<thead>
<tr>
<th>Clinical focus areas</th>
<th>Technology focus areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Musculoskeletal</td>
<td>Advanced functional materials</td>
</tr>
<tr>
<td>Cardio-respiratory</td>
<td>Patient-specific devices and therapy</td>
</tr>
<tr>
<td>Neurological</td>
<td>Closed loop and autonomous systems</td>
</tr>
<tr>
<td>Mental health</td>
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</tbody>
</table>

For more information, and for a full list of academic and industrial partners, please visit the programme website:

This EPSRC-funded Programme Grant (EP/P031684/1). The programme vision is to establish controlled next generation multifunctional AM and translate this to industry and researchers. Initially focussing on novel electronic and pharmaceutical/healthcare applications, this research has moved beyond single material AM by exploiting the potential to deposit multiple materials contemporaneously for the delivery of spatially resolved function and structure in three dimensions. Owing to potentially radical differences in physical state, chemistry and compatibility, the primary challenge addressed lies at the interface of the deposited materials.

After a highly successful mid-term review, this programme grant is due to end in April 2024.

In collaboration with the universities of Warwick and Birmingham, as well as with the School of Pharmacy and Physics at Nottingham, CIAM is continuing a deeper exploration in the area of multifunctional AM through this EPSRC-funded Programme Grant (EP/P031684/1).

For more information, and for a full list of academic and industrial partners, please visit the programme website:
Project highlights

A biopesticidal lease of life for crop protection: Additive Manufacturing for tailored timing of biopesticide release by natural triggers

Principal investigator: Prof Ricky Wildman
Co-investigators: Prof Cameron Alexander, Prof Simon Avery, Dr Almudena Ortiz-Urquiza, Prof Felicity Rose

The need to meet the increasing demand for food while growing crops more sustainably is a major global challenge. For more sustainable crop production, there is an urgent need to reduce reliance on synthetic chemical pesticides on farms. This project (funded by BBSRC, BB/X005399/1) introduces AM capability to engineer the encapsulation and delivery of biopesticidal fungal spores via concepts similar to those used for 3D printed ‘polypills’ in biomedicine.

Reactive fusion – revolutionary technology for 3D printed polyurethane products

Project team: Dr Ian Halliday, Prof Chris Tuck, Prof Richard Hague, Prof Ricky Wildman, Dr Yinfeng He, Dr Le Ma

This InnovateUK (ICURE) funded project aims to transform polymer AM by using chemistry rather than heat or ultra-violet light to convert powdered and liquid materials into engineering grade polyurethane and polyurea components. These high-performance materials are available all with the design freedoms that AM allows.

AI Synthesis of Structures for AM (ASSAM)

Principal investigator: Dr Ian Maskery
Co-investigators: Dr Luke Parry and Prof Ender Ozcan

This project launches a new field of research combining digital manufacturing and cutting-edge artificial intelligence (AI). It creates an AI design assistant capable of generating 3D manufacturable structures that go beyond current design practices. This is grounded on suitable learning techniques based on deep neural networks, sources of training data, and the manufacturability of AI designs for a range of AM processes. This project seeks to address the question: what can AI learn from nature and apply directly to engineering problems?
Doctoral research

CfAM has an extensive portfolio of doctoral research projects, spanning mechanical engineering and materials research to biochemistry and pharmaceutical investigations. Overall, CfAM is currently hosting more than 40 doctorate students.

Over the recent years, the EPSRC Centre for Doctoral Training (CDT) in Additive Manufacturing has played a particularly important role in the doctoral research taking place at CfAM. Led by the University of Nottingham in collaboration with the universities of Liverpool, Loughborough, and Newcastle, the CDT recruited its final cohort of students in 2019. The students in this cohort are now finalising their doctoral projects.

Additionally, CfAM has intensified its collaboration with other schools and faculties at The University of Nottingham, (including Pharmacy, Chemistry and Physics) and with industrial partners (including GSK, AstraZeneca, Querlient Sciences, MTC, Siemens, and many others).

All doctoral students at CfAM benefit from their participation in a comprehensive programme of support activities. These include regular team building events, training sessions, academic seminars, guest lectures and presentations by visiting thought leaders, and sessions with industry specialists, such as recruiters. In a number of cases, CfAM was able to send doctorate students on bespoke additional training programmes in specialist subjects, such as Prince2 project management, and academic writing trainings.

The academics at CfAM are keenly aware that the doctorate students we are training now and have trained in the past are not only essential for our current research activities but will also act as multipliers for our future initiatives. Irrespective of whether they will pursue a career in academia or industry, in the UK or elsewhere, they will be strong and lasting ambassadors of CfAM. We would like to use this opportunity express how much we value them and their contributions.

<table>
<thead>
<tr>
<th>PhD Student name</th>
<th>Topic of doctoral project</th>
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<tbody>
<tr>
<td>Ben Sutcliffe</td>
<td>Development of a holographic 3D printing system to produce sustainable cultured meat</td>
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<tr>
<td>Cristina Ferro Barbosa</td>
<td>Design, modelling and biofabrication of osteochondral scaffolds</td>
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<tr>
<td>Jonathan Austin</td>
<td>Additive Manufacturing of OD/2D heterostructure for optoelectronic devices</td>
</tr>
<tr>
<td>Robert Plant</td>
<td>Using stereolithography to construct complex geometries onto non-standard substrates for the purpose of electronics packaging</td>
</tr>
<tr>
<td>Mohga Youssif</td>
<td>Investigating TMPS scaffold design using SLA for facial reconstruction</td>
</tr>
<tr>
<td>William Pritchard</td>
<td>3D printing proteins for continuous flow biocatalysis and biosorption</td>
</tr>
<tr>
<td>Yassin Ziar</td>
<td>Modular Additive Manufacturing for next-generation hydrogen storage</td>
</tr>
<tr>
<td>Alya Alhammadi</td>
<td>Sustainable feedstock for metal additive manufacturing</td>
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<tr>
<td>Tien Thuy Quach</td>
<td>Novel micro/nano scale characterisation of interfaces in multimaterial Additive Manufacturing</td>
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<tr>
<td>Han Wang</td>
<td>Workflow optimisation to release environmental network effects in AM</td>
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<tr>
<td>Ellie Ward</td>
<td>Targeted near-infrared quantum dots for next generation health diagnostics</td>
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<tr>
<td>Thomas Smith</td>
<td>Enhancing magnetic shielding using the design freedom of Additive Manufacturing</td>
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<tr>
<td>Oliver Nelson-Dumont</td>
<td>3D inkjet printing for electronic materials</td>
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<tr>
<td>Diego Della Crociata</td>
<td>Creating new energy-absorbing structures for automotive applications using Additive Manufacturing of lightweight steels</td>
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<tr>
<td>Charles Heaton</td>
<td>Inkjet deposition of low dimensional materials for flexible healthcare devices</td>
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<tr>
<td>Daniel Padrao</td>
<td>Thermofluid optimisation of AM high heat flux components for fusion</td>
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<tr>
<td>Doa’a Ismail</td>
<td>Felodipine bioavailability enhancement through polymeric-lipid extrusion 3D printing</td>
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<tr>
<td>Binchu Ollekkatt</td>
<td>3D printing with 1D functional nanomaterials</td>
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<tr>
<td>Xiao Yuan Wang</td>
<td>Synthesis and continuous manufacture of novel, high performing polymeric lubricants for next-generation electric transportation</td>
</tr>
<tr>
<td>Kristian Plender</td>
<td>Implementing 3D printing for the long-term release of biomacromolecules</td>
</tr>
<tr>
<td>Bethany Husband</td>
<td>Inkjet printing of polynimid replacement materials</td>
</tr>
<tr>
<td>Valeria Gonzalez Abrego</td>
<td>3D printing of complex anatomical features in tissue models through MM- Py/SLA</td>
</tr>
<tr>
<td>Jordan Hill</td>
<td>Integrating molecular self-assembly with Additive Manufacturing for biomedical applications</td>
</tr>
<tr>
<td>Shreja Basak</td>
<td>The impact of process planning on cost and production losses in Additive Manufacturing</td>
</tr>
<tr>
<td>Arielle Torres</td>
<td>Fabrication of polyurethane composites via reactive binder jetting using a dual-ink binding system</td>
</tr>
<tr>
<td>Mostafa Mohamed</td>
<td>Development and experimental validation of children’s biomimetic adaptive myoprosthetic hand with sensory feedback</td>
</tr>
<tr>
<td>Alaeldar Bulloch</td>
<td>Design of metal structures of custom composition using Additive Manufacturing</td>
</tr>
</tbody>
</table>

Additionally, CfAM students and staff at the June 2022 away day.
The capabilities enabled by AM are opening up a new world of advanced engineering components. Such components include new kinds of lightweight structures for transport applications, novel prosthetic limbs, and complex pharmaceutical products. As the activities outlined in this report show, engineers and scientists are benefitting from the ability to create unprecedented degrees of complexity and are grasping this by developing conceptually new products and transformative manufacturing approaches.

The Additive Manufacturing and 3D Printing MSc programme at the University of Nottingham is available as a bespoke postgraduate taught opportunity for those interested in gaining in-depth knowledge and understanding of Additive Manufacturing and 3D printing technology. As a 12-month course, students are taught by career researchers at CfAM, who are world-leading experts and have access to CfAM’s laboratory. Students gain the skills needed to:

- evaluate the application of AM technologies
- apply methods in a project context
- design additively manufactured devices
- undertake individual research projects
- critique, analyse, and communicate research findings

The course is delivered in a one-year, full-time format, starting each September. Entry requirements for this course are a 2:1 undergraduate degree (or international equivalent) in a relevant subject such as engineering, maths, physics, chemistry, pharmacy, design or any science-related discipline. For more information, please visit our website.

Starting with the academic session 2022-2023, the course is led by its new Programme Director Dr Lyudmila Turyanska. We thank the outgoing Programme Director Dr Martin Baumers for leading the course successfully in its first five years and wish the new Programme Director all the best for her tenure.

What our alumni say:

As an international graduate and passionate about 3D printing, I found a life-changing experience in the Additive Manufacturing and 3D Printing MSc course, which is designed by renowned researchers. I can proudly say it has enhanced my personal growth, soft skills and facilitated in-depth knowledge on the techniques currently adopted in industry and current research [...]. In my professional day-by-day life, I use the knowledge I have gained to help customers from the sectors of TV and film production, food processing, AI training, aeronautics and defence to adopt and use AM technology in the best possible way for each application.

Moises Arturo Clemente Guzman (graduated 2022)

Attending the Additive Manufacturing and 3D Printing master’s programme at the University of Nottingham has been one of the best decisions I have ever made. The programme exceeded my academic expectations with a well thought through course structure, up-to-date course material, engaging lectures and tutors, and second-to-none facilities. Perhaps more importantly, the University of Nottingham and the Centre for Additive Manufacturing have cultivated a warm and welcoming environment emphasising personal development, building relationships, and having fun.

Magnus Kristensen (graduated 2022)

For more information, please visit the AM MSc course website:

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Students on the 2022-23 cohort of the AM MSc course together with the Course Directors.
AM facilities

CIAM’s laboratories host a globally unique portfolio of developmental and commercially available AM systems. This is supported by a state-of-the-art suite of analytical devices in a dedicated materials characterisation laboratory. Together, our laboratories form a vital tool for establishing new avenues of academic and industrially focused research.

Among our large portfolio of research and commercially deployed AM systems, CIAM’s main laboratory in the Advanced Manufacturing Building on Jubilee Campus boasts specialist and bespoke systems that are not available elsewhere. These include experimental multimaterial 3D ink jetting systems, ranging from small exploratory research platforms to large systems such as our PIXDRO Toucan and Notion jetting systems, high-temperature liquid metal jetting systems (MetalJet), and custom-built multimaterial high-resolution AM systems. We are also proud to have recently installed the Aconity metallic powder bed fusion system, which is an open architecture system permitting the processing of multiple metals in a single powder bed process.

This is complemented by our clean room facility (supported by the Wolfson Foundation) which provides a setting in which processes are shielded from environmental pollutants and light sources. This environment considerably widens the palette of materials for 3D inkjet and extrusion printing platforms and is used primarily for pharmaceutical, biological, and electronics-oriented research. It is equipped with a comprehensive suite of 3D ink jetting and analysis equipment, alongside pharmaceutically focused material extrusion systems.

Recent developments include:

- Installation of the Aconity metallic powder bed fusion system in conjunction with the Aerosint powder deposition system ( pictured on page 22)
- Installation of the Notion/ Xaar jetting platform
- We congratulate our Trainee Technician Adam Whitbread to passing his NVQs in Engineering in September 2022
- We have now made our laboratories available in a virtual lab tour which you can visit here:

Aerosint powder recoating system permitting the selective deposition of two distinct metallic materials.
Additive Biofabrication Laboratory

The Additive Biofabrication Laboratory located within the Biodiscovery Institute is a joint venture between the School of Pharmacy and the Faculty of Engineering at the University of Nottingham. Additive biofabrication is the use of 3D printing technologies to create structures that can direct the behaviour of biological systems. This facility is unrivalled in the UK in its consolidation of the latest technologies and boasts a plethora of bioprinting equipment, including a unique portfolio of the latest light-based biofabrication technologies for high-resolution AM for healthcare applications, all of which are housed within a dedicated cell culture suite where live biological materials can be used.

Technologies available span from small scale exploratory systems to develop new materials to cutting edge commercial equipment and bespoke systems built in-house. They include multiphoton lithography/two-photon polymerisation (MPL/2PP), projection microstereolithography (pµSLA) and computed axial lithography/volumetric additive manufacturing (CAL/VAM). With these, cell scale (10s microns) to sub-cell scale (<1 micron) resolutions can be achieved at the high fabrication rates needed for live cell printing. By housing this equipment within biological safety cabinets, cell-laden bioprints can be manufactured in a sterile environment in a clinically relevant manner.

AM laboratory in Clinical Engineering

In 2022, we established a new AM laboratory at Queens Medical Centre (QMC), in a joint venture with the Clinical Engineering department at Nottingham University Hospitals NHS Trust (NUH). The lab, which includes HP MultiJet Fusion 580, Ultimaker S7, and Formlabs Form3B systems, provides a central facility for NUH staff who would like to explore the use of AM in clinical applications. This venture is designed to aid translation of research from CfAM and the wider AM community into hospitals, identifying current opportunities and future research needs. For further information, please contact Prof Ruth Goodridge.
Engaging the public

Outreach events

- Success in the Ingenuity Programme with two projects being selected as finalists (“Improve Health” and “Build Community”)
- Participation in the 2021 Women in Engineering Day by Masoomeh Bazzar and Salome Sanchez
- Participation in the Annual Engineering Research Showcase in the Pitch Perfect, Poster and Three Minute Thesis competitions
- Winner of the Tri-Campus Awards in the Covid-19 Impact category
- Media interviews on 3D-printed personalised pills at BBC Radio 4, BBC Radio Nottingham and Al Jazeera English TV by Dr Laura Ruiz Cantu, Dr Yinfeng He and Prof Ricky Wildman
- Continued school outreach activity at Woodthorpe School
- Participation in the Real Science in Schools Symposium as part of the Nottingham Festival of Science and Curiosity (FOSAC)
- Contributions to the IntoUniversity Mentoring Celebration programme
- Supporting the Three Minute Wonders 2022 initiative – East Midlands Branch
- Mentoring role in the Able Orchestra Project, which won Project of the Year at the Final Showcase

Royal Society Summer Science Exhibition

We were honoured to be able to present our research at the Royal Society’s prestigious Summer Science Exhibition in July 2021, which was run as a digital event. We are delighted to again present our research at the Royal Society Summer Science Exhibition in 2023.

Our contribution in the form of online lectures, video clips, and interactive content demonstrated the use of AM technology to print personalised ‘polypills’. Polypills can be particularly helpful, for example, for the very young or the elderly who find it difficult to swallow pills, which is often made worse by having to take many different medications. The polypill can be loaded with several different medications and can be personalised to deliver a patient-specific combination of medication at just the right dose depending on the patient’s weight, sex, ethnicity and genetic factors etc. 3D printing of polypills can also enable the local manufacture of medication at community pharmacies, so revolutionising the supply chain and could be especially useful, for example, in war zones and low income countries where transport links can be limited.

Future scalability of AM event

Academic and industry-focused workshop held on 10 November 2022. CFAM was delighted to host an agenda-building workshop focusing on the operations management of AM technology. Co-hosted by Dr Martin Baumers and Shreeja Basak from the University of Nottingham and Prof Matthias Holweg from the University of Oxford, this workshop was attended by a range of industrial and academic stakeholders.

The workshop investigated the role of the operations managers in the context of AM technology, the possibility of Lean approaches, and whether production losses represent a barrier to the adoption of AM technology. Moreover, data-driven methods and metrics to improve AM operations were evaluated.

For more information, please see the article here:
Additional grant successes

Advanced multimaterial wing structure created with AM.

<table>
<thead>
<tr>
<th>Title</th>
<th>Sponsor</th>
<th>Principal Investigator</th>
<th>Budget</th>
</tr>
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<tbody>
<tr>
<td>Dialling Up Performance for On Demand Manufacturing</td>
<td>EPSRC</td>
<td>Ricky Wildman</td>
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<tr>
<td>Enabling Next Generation Additive Manufacturing</td>
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<td>Dial-up Engineered Microstructures for Advanced Additively Manufactured Metals (DEMAMM)</td>
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<td>Next Generation Rehabilitation Technologies</td>
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<td>Intelligent Structures for Low Noise Environments</td>
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<td>AIM3: Additive and intelligent manufacturing of multi-functional membranes</td>
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<td>Metal Jetting of Functionally Graded Materials</td>
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<td>Accelerated Discovery and Development of New Medicines: Prosperity Partnership for a Healthier Nation</td>
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<td>Silicone Jetting Micro-SLA</td>
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<td>IDR-Engineering sustainable squalene analogs for novel</td>
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<td>Next Generation Biomaterials Discovery</td>
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<td>Savi: NSF-EPSRC A Transatlantic Institute for Volumetric Powder Bed Fusion</td>
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<td>Development and exploitation of a bioactives-free technology for tackling fungal threats to food security, goods and health</td>
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<td>AM and 3DP in Clinical Practice</td>
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<td>A biostuccidal lease of life for crop protection: additive manufacturing for tailored timing of biopesticide release by natural triggers</td>
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<td>Low-cost Titanium for Combat Protective Equipment via Laser-Powder Bed Fusion</td>
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<td>Accelerated commercialisation of the Nottingham reactive 3D printing process</td>
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Funders, partners and collaborators

We thank all our partners who have supported the delivery of our research vision, including our industrial collaborators, allied research institutions and technology organisations. We gratefully acknowledge the support we receive from all of our funding partners, with special thanks and recognition to our core funder, the EPSRC.

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IT
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Arkema
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Arthritis Research UK Tissue Engineering Centre
AstraZeneca
AWE
BBRC
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CPI
CSIRO
Delphi
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University of Cambridge
University of Delaware
University of Liverpool
University of Reading
University of Strathclyde
University of Warwick
UTC Aerospace Systems
Velcro
Wolfson Foundation
Xerox PARC

Biofunctionalised gyroid test specimen made via photopolymeric AM.
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The University of Nottingham has made every effort to ensure that the information in this brochure was accurate when published. Please note, however, that the nature of this content means that it is subject to change, therefore consider it to be guiding rather than definitive.