

Research Agenda Sustainability

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What is the National Manufacturing Institute Scotland (NMIS)?



A group of industry-led manufacturing **R&D** facilities where **Academia**, **Industry** and the **Public Sector** work together to transform **skills**, **productivity** and **innovation** in **advanced manufacturing** and **Sustainability**.



NMIS Innovation Eco-System



NMIS
National Manufacturing
Institute Scotland

**Lightweight
Manufacturing Centre**



Composite Recycling - Wind

PRoGrESS

Products from Recycled Glass fibre at Economic and Sustainable Scale



PRoGrESS

- £2M, 3 years project
- More than 10 years research work
- Funded by the industrial partners & Innovate UK – Smart Grant
- UK first (world first?) wind turbine upcycling system



<p>AKER OFFSHORE WIND</p>	OEM
<p>suez</p>	Waste Management
<p>CUBIS SYSTEMS A CRH COMPANY</p> <p>GRP SOLUTIONS great people great products great service</p>	Material Manufacturer and Distributor
<p>Composites UK Trade Association</p>	Trade Association
<p>NMIS National Manufacturing Institute Scotland</p> <p>Lightweight Manufacturing Centre</p> <p>ACG Advanced Composites Group</p> <p>University of Nottingham UK CHINA MALAYSIA</p>	Research Organisation

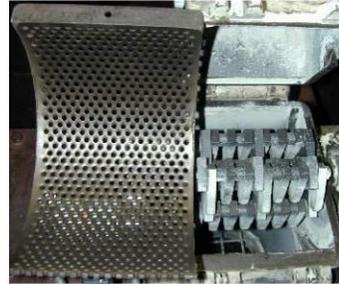


Composite Recycling - Wind

Technology Flow



Disassembly



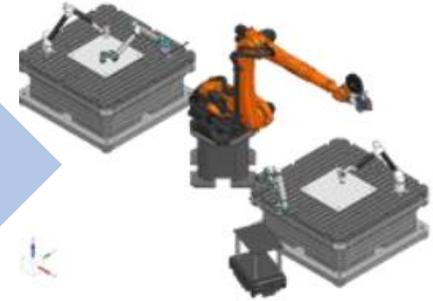
Size Reduction



Recycling



Reformatting



Manufacturing

Material Flow



End of Life Waste



Scraped Material



“Regenerated”
fibres
Recycled Fibre



Recycled Fibre Material



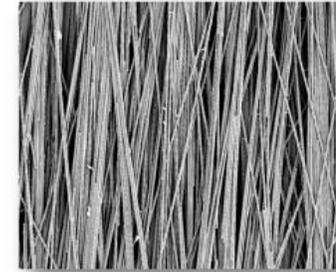
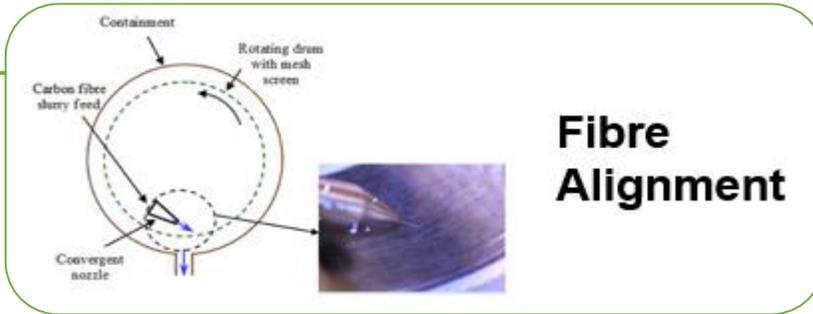
Sustainable Products



Re-Formatted rGF Materials

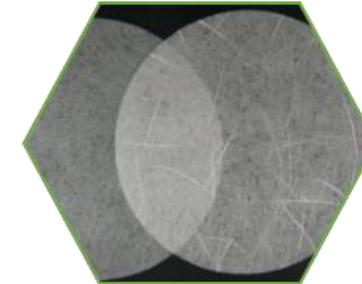
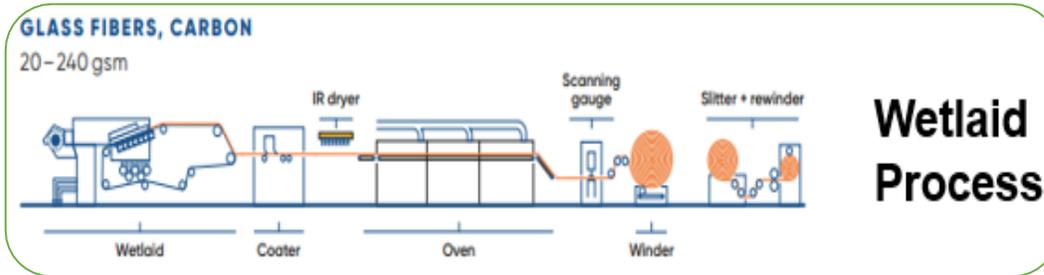


Recycled Glass Fibre

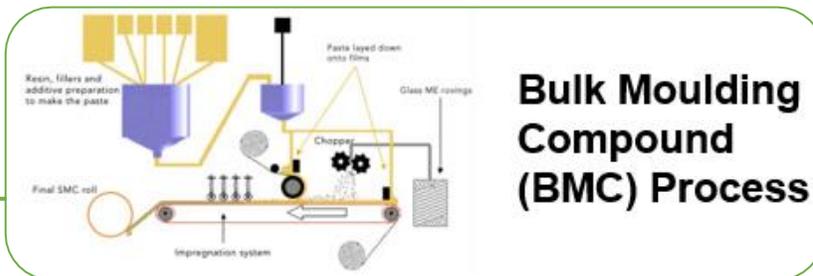


Aligned short fibre (30gsm)

Vacuum Infusion – 26% Vf
Flexural Strength – 220 MPa
Flexural Modulus – 10 GPa



Vacuum Infusion – 12% Vf
Flexural Strength – 112 MPa
Flexural Modulus – 5 GPa



Vacuum Infusion – 20% Vf
Flexural Strength – 61 MPa



Recycled Fibre Products

Wetlaid Process

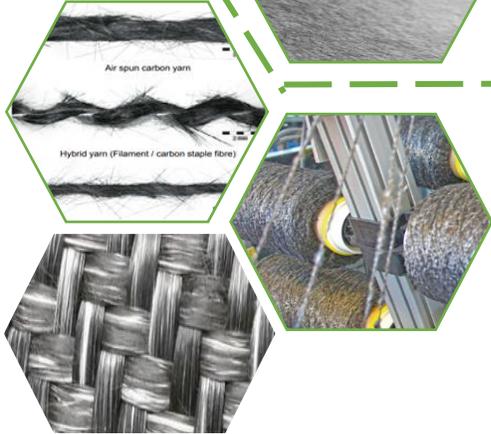
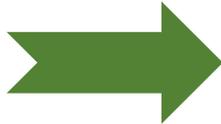


- TFP type Nonwoven
- High-Performance Aligned Fibre Mat



- Compression Moulding
- Preforming
- Tape Laying

Yarn Spinning Process

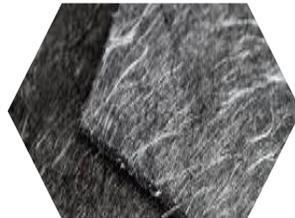


- Hybrid Fibre Yarn
- Recycled Fibre Fabric



- Braiding/Waving
- Filament Winding
- Additive Manufacturing

Nonwoven Process



- Hybrid Nonwoven
- Multifunctional Nonwoven



- Rapid Manufacturing



Composite Recycling - Aerospace

- Value chain mapping
- Next steps



EoL Aircraft Recycling – Project Partners



Disassembly



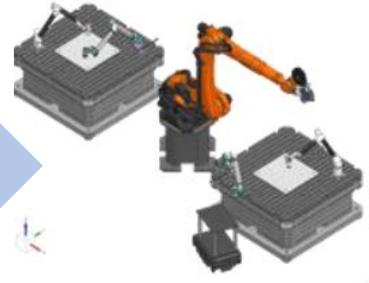
Size Reduction



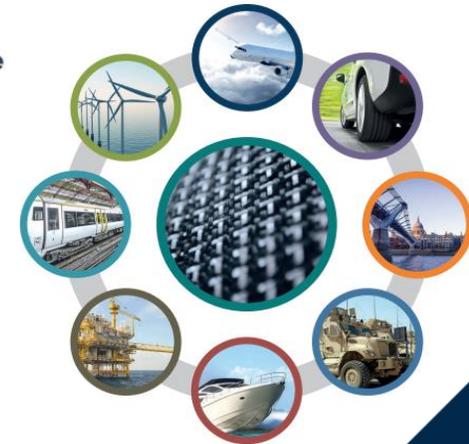
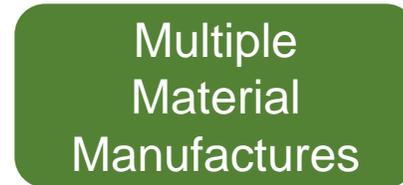
Recycling



Reformatting



Design
Manufacturing



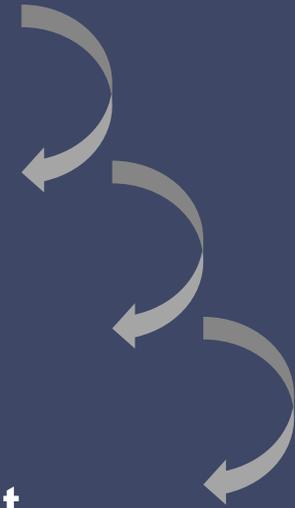
Boeing 787 Wingtips



Composite Recycling

- Pre-processing
 - Disassembly
 - Size reduction
- Matrix deconstruction
 - Thermal
 - Chemical
- Reinforcement reformatting

- Process development
- Material development
- Product development
- **Life Cycle Assessment**



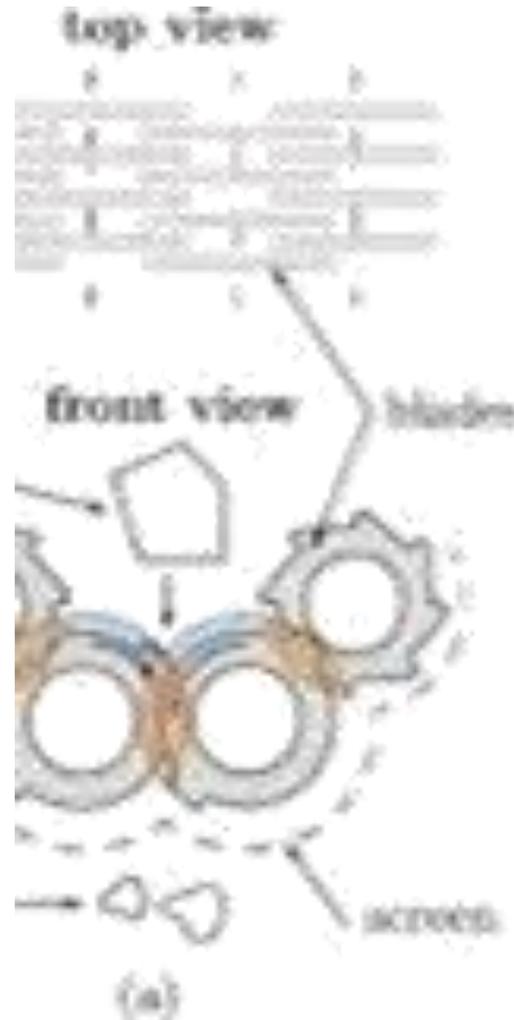
01 Disassembly

- **Sorting.** Accessing legacy data to identify target and component provenance.
- **Research**
 - **Digital:** PLM and AI optimisation of disassembly
 - **Mechanical:** Automation of disassembly process
- **Grading.** Assigning component to a recycling value stream and routing towards the appropriate recycling and material manufacturing technology.
- **Research**
 - **Digital:** Optimisation of workflow to balance inventory v demand for product



02 Size Reduction

- **Shredding** will be a research opportunity to optimise the quality and size of composite materials to be introduced into the separating phase.
- **Fibre length** is a critical factor in downstream process and in the performance of engineered materials.
- Tolerance of and robustness to different composite material **grades** and **thicknesses** is desirable.
- Tool **life** will also play a factor in the economic cases and the opportunity for remanufacturing of teeth and rollers exists



02 Size Reduction, cont

- Blunt force honeycomb panel penetration test.
- Failure modes:
 - Top skin: direct bearing and shear
 - Lower skin: bending and tension
- Highly sensitive to skin thickness



03 Matrix deconstruction

- Thermal
 - Fluidised Bed
 - Pyrolysis
 - Hydrolysis
- Chemical
 - Solvolysis
- Fibre grading
- Matrix reclaim



Boeing / University of Nottingham, Fluidised Bed



04 Reinforcement reformatting

○ Material architectures include:

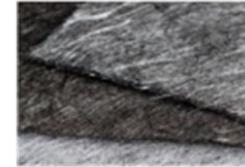
- Fibre reinforced granules (micro-compounder)
- Filament (FDM)
- Non-wovens
- Yarns
- BMC/SMC
- Spread tow
- Tapes
- Thin ply fabrics
- Co-mingled thermoplastics



Recycled Carbon Fibre



Source: ELG CF Ltd
Milled Powder



Source: ELG CF Ltd
Nonwoven



Hybrid Yarn [1]



Aligned Tape [3]



Source: ELG CF Ltd
Pellets



Source: MIT, Fletcher, N.C.
3D Preform



Aligned Tow [2]

Increasing Potential Value

Higher Production Rate



04 Reinforcement reformatting; cont:

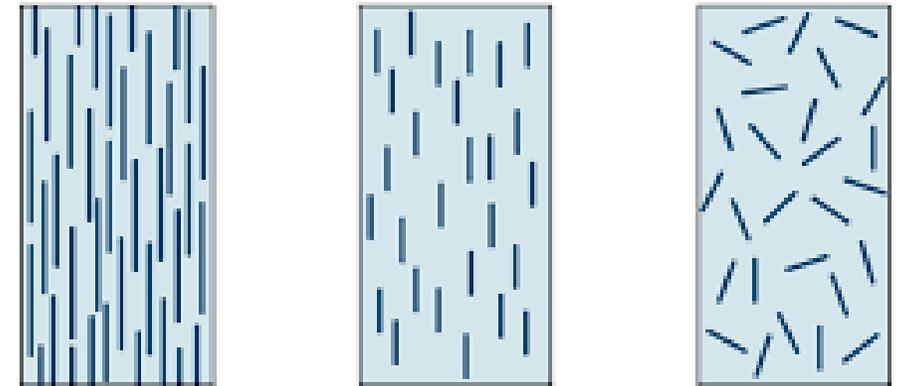
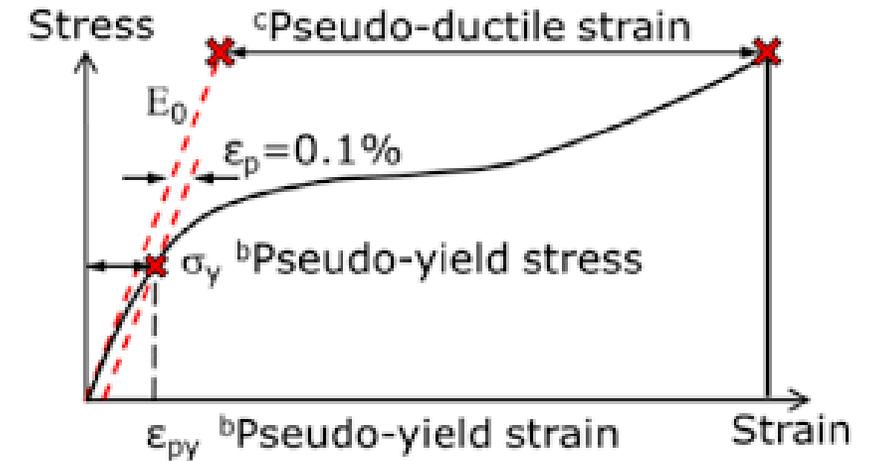
Example research theme:

- Spun yarns → spread tow tape → thin ply

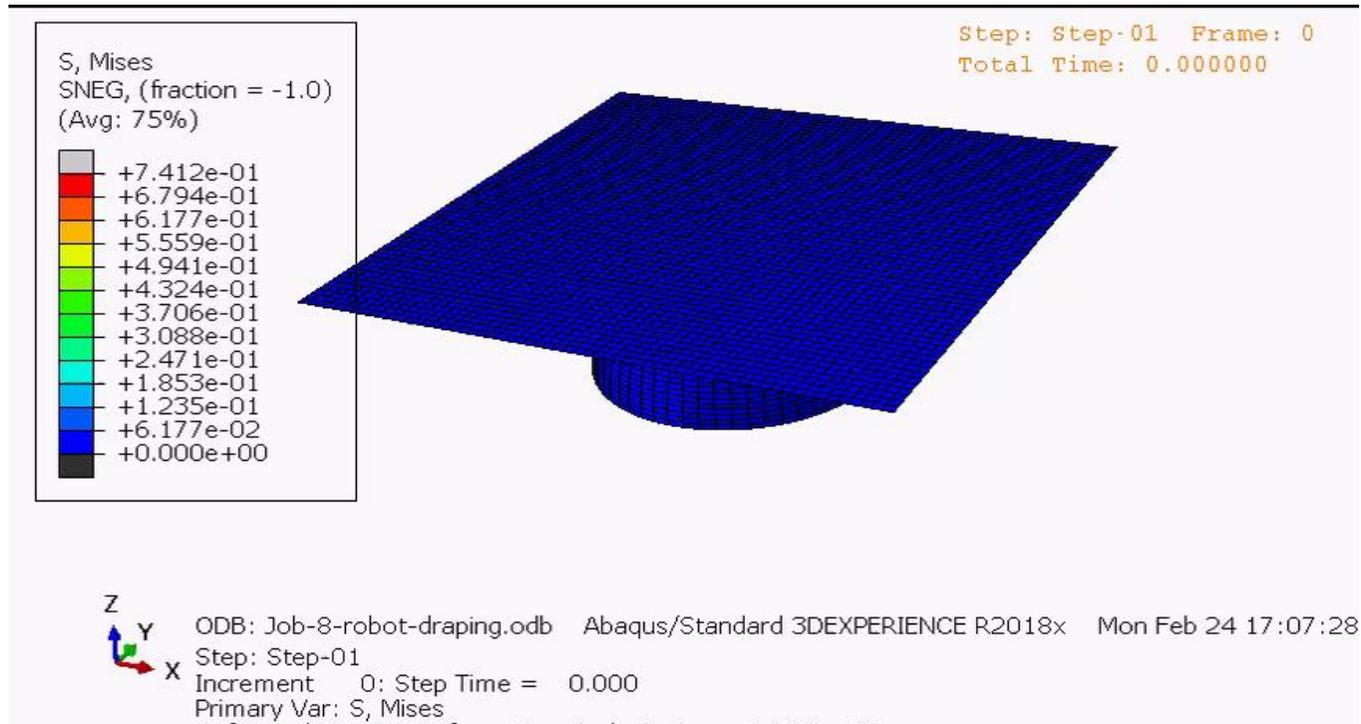


05 Fibre Alignment

- Aligned, short fibre uni-directional materials are key to extracting the maximum value from recycled composites.
- Partnerships with other research institutes will be created to deliver translational research in this field.
- The Composite Sustainability Test Bed will provide a Wet Laid manufacturing line to screen materials and develop processes; at scale.
- The Future Fibre Test Bed will provide a range of synergistic materials in fibre and film format.



06 Material Synthesis



Material synthesis from correlated data, digital twinning of recycled materials, to optimise physical handling and for mechanical and quality assurance.

The material provenance and in process quality assurance must be reflected in the tools that the Engineers select when defining their products.



07 High Value Design

- Design and Analytic tools and methods for these materials and manufacturing process
- Developed and validated in collaboration with R&T Teams.
 - Signatory
 - High Level / Low Level
- Material and Component Certification
- Supply Chain Development



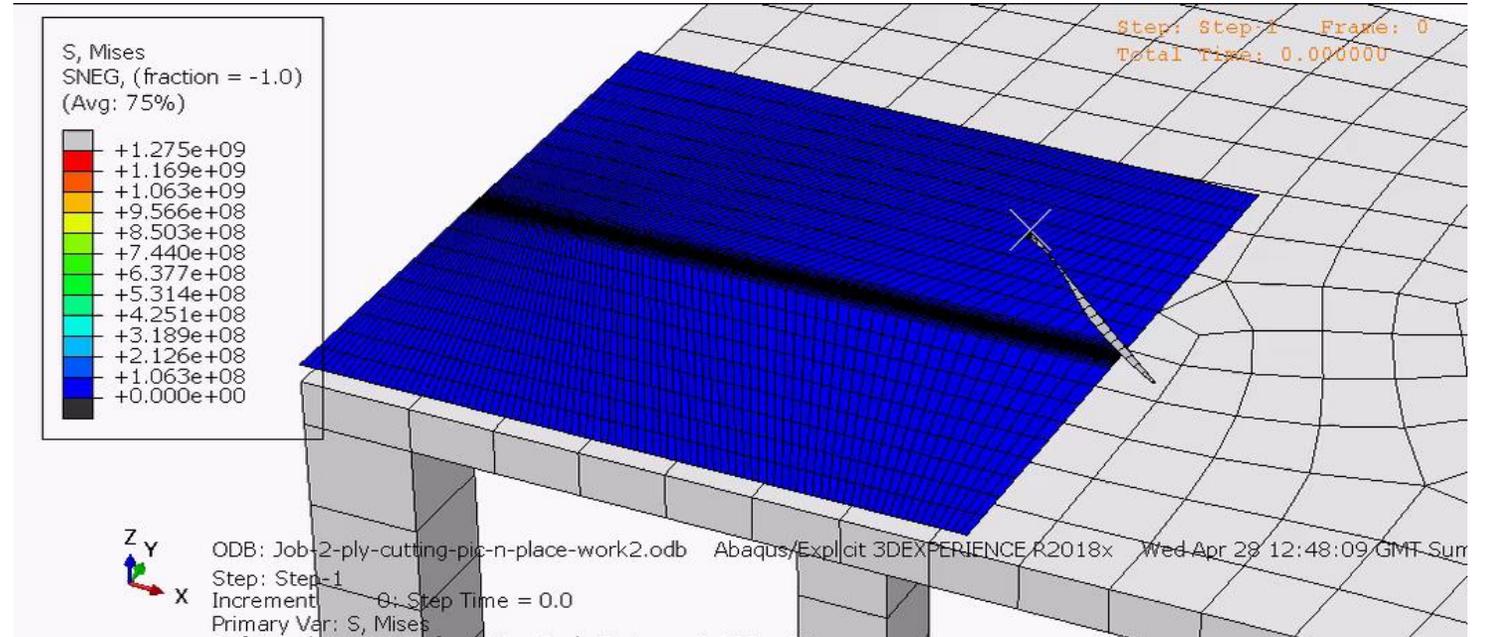
07 High Value Design; cont.

- Recycled materials are not necessarily lower value materials.
- Short fibre aligned uni-directional tapes can exhibit pseudo-plastic behaviours with a degree of ductility that are potentially desirable for applications where benign failure mechanisms are desirable, such as aircraft seating.



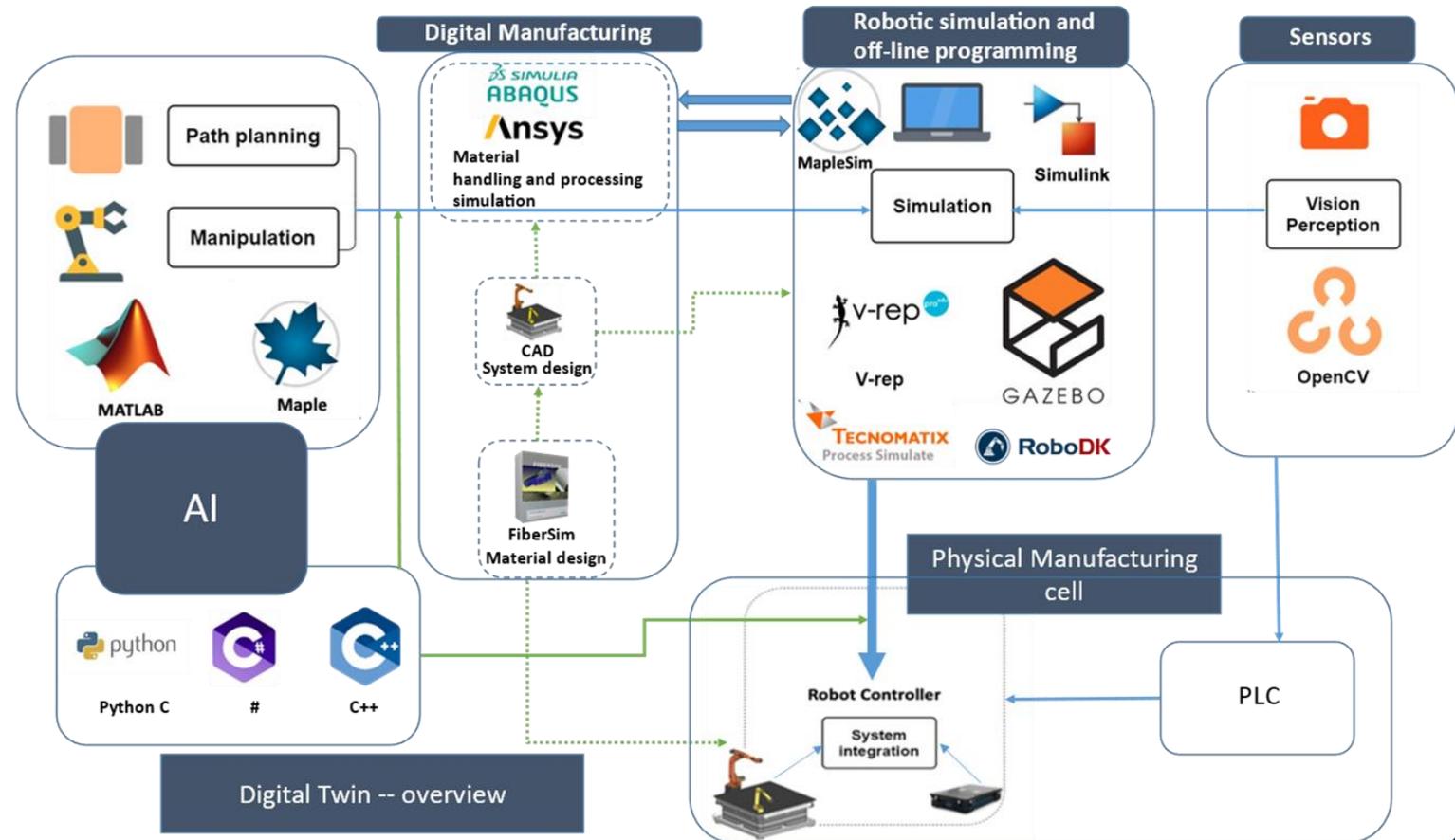
08 Analysis Methods

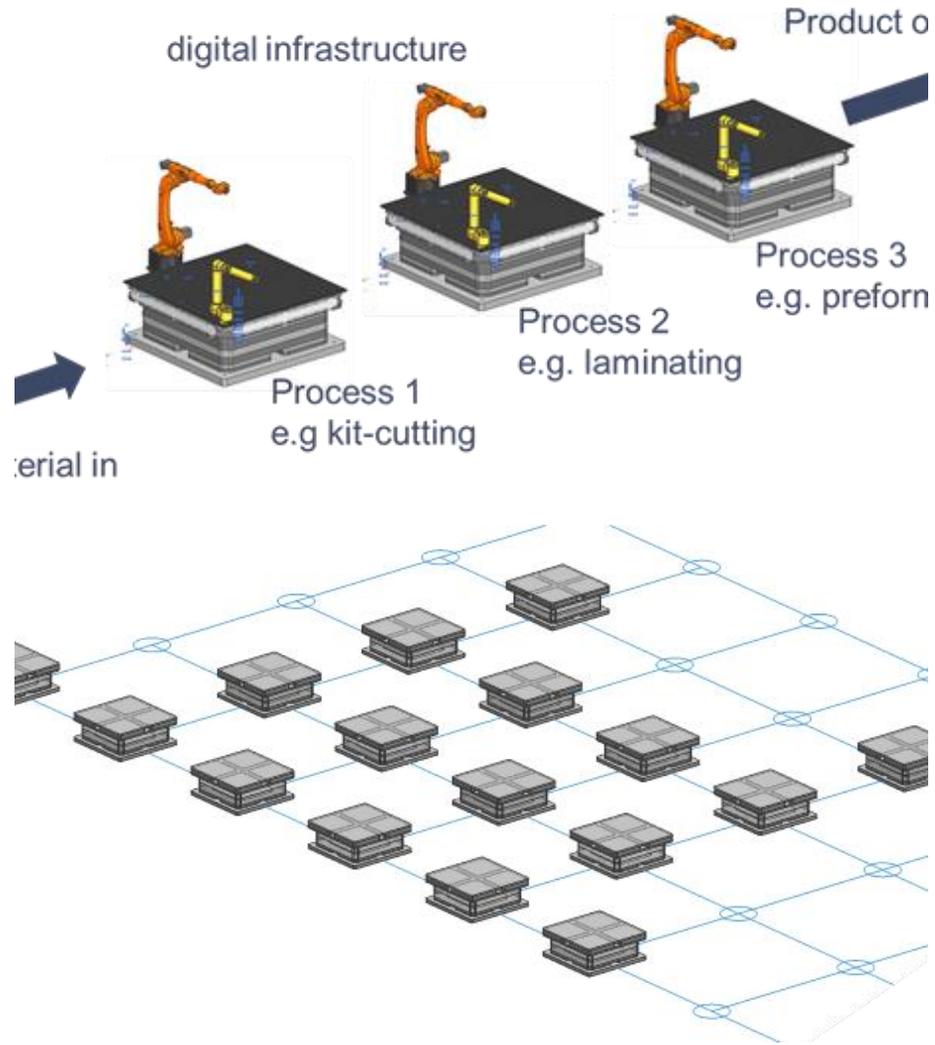
- Simulation tools will be developed that enable Designers, Engineers and Supply Chain Managers to include such products within their portfolio.
- Simulation extends beyond classical laminate theory into manufacturing process simulation seen here looking at material handling and draping for the LMC's Reconfigurable Pilot Line.
- Multi-physics and Optimisation



09 DfM

- The Digital suite of Design for Manufacturing tools and methods.
- Product and manufacturing optimisation.





10 Prototyping; LMC's RPL



11 LCA

- Mapping of embedded costs, inc CO2, and relationships.
 - Material manufacture
 - Product manufacture

Micro Circular Economy

