ACCIS Developments in Composites Manufacture

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Outline

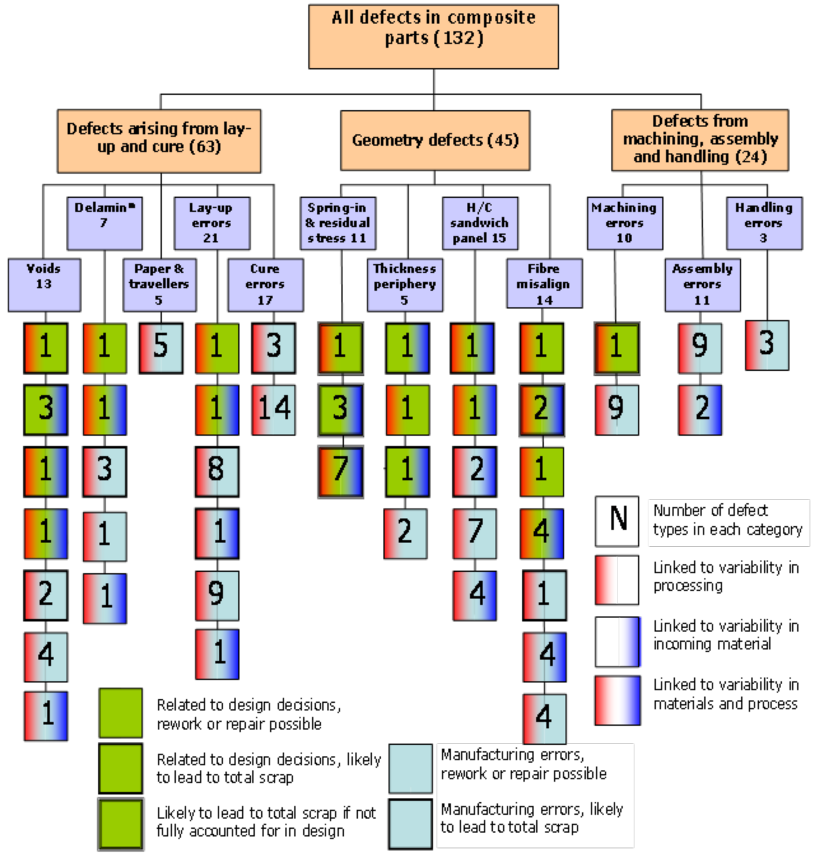
- Areas of current manufacturing research in ACCIS
  - Approaches to in-process inspection
  - Understanding the fundamentals of the tape laying process
  - Approaches to higher speed and automated manufacture of broadgoods, and wider issues of understanding costs and costing
  - Development of tow steering/dry fibre placement technology, materials characterisation and new applications
  - Sources of dimensional instability and spring-in for large structures
  - Impact of process-induced fibre waviness on mechanical performance, and wider issues of sources and control of defects
  - Fundamental processing issues such as wetting and interfacial properties
- Proposed EPSRC Centre for Innovative Manufacture in Composites

Why in-process inspection?

- The normal standard for inspection of high performance composite parts is to carry out the first critical inspection post-moulding
- At that point the components have a significant added value, even a small part could be >£1000 at this stage
- Defective parts must be reworked, repaired or scrapped and even if they can be supplied to the end user additional concession costs will be accrued
- The need to critically check parts at this stage leads to 100% inspection and thus to high inspection costs
- The rework/repair/reinspect/concession loop can significantly disrupt the flow of a production line – a critical issue for high rate production

Approaches to in-process inspection

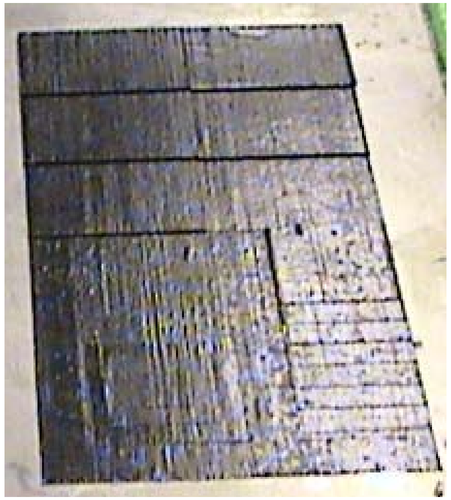
- Working through defect taxonomies can help to understand how defects arise
- Working through inspection records and defect databases can give focus on which defects have the most economic impact
- A clear understanding of the lay-up and reinforcement drape processes can be used to help define where inspection is critical

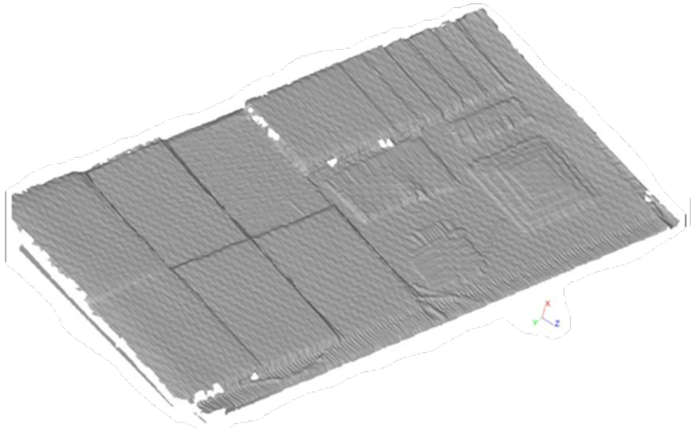


- Our initial focus is on geometrical defects such as bridging that occur during lay-up, and surface scanning techniques have been investigated as a first step

Experimental verification 1

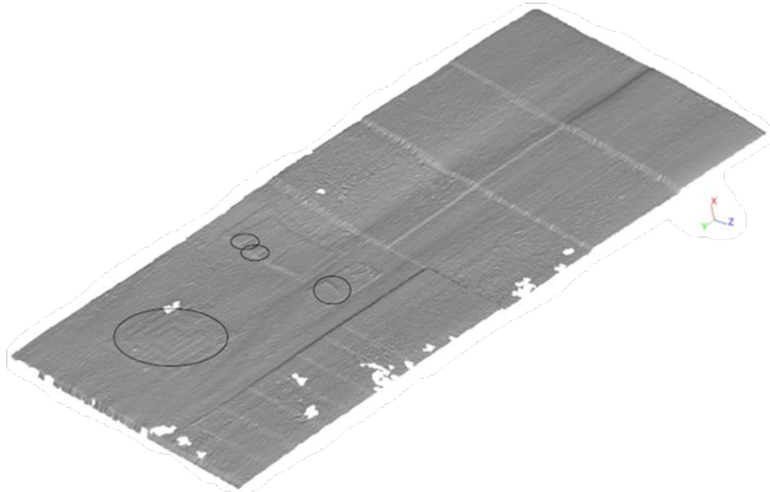
- Using T Scan equipment provided by Central Scanning Limited
- Lay-ups of UD prepreg, uniweave NCF and 5HS woven cloth were hand scanned
- Surface geometry can be picked up fairly reliably for further processing





5HS

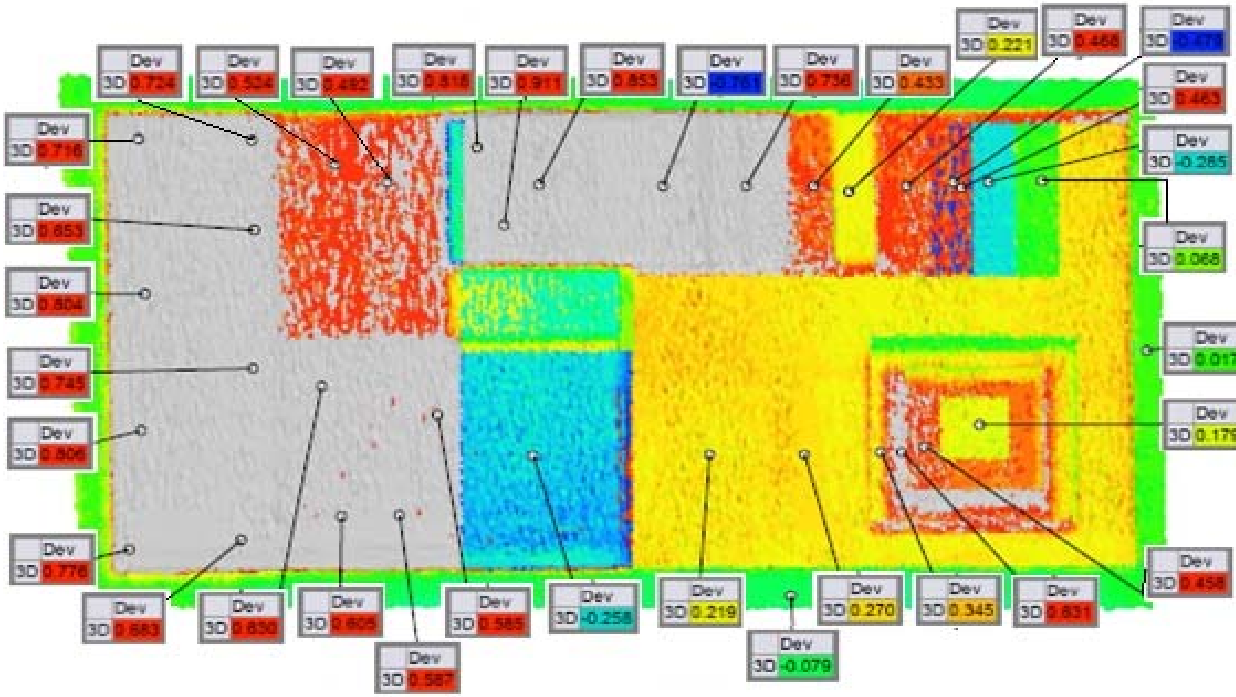
NCF



Uni prepreg

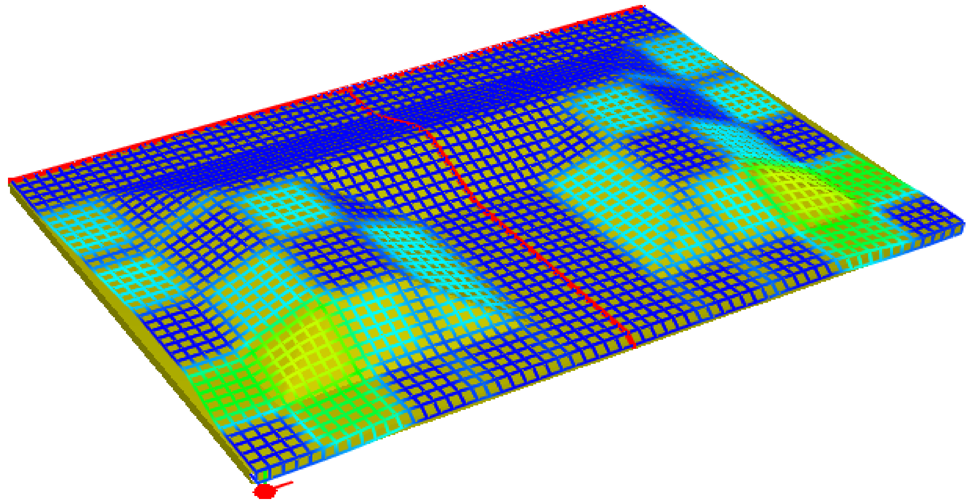
Experimental verification 1

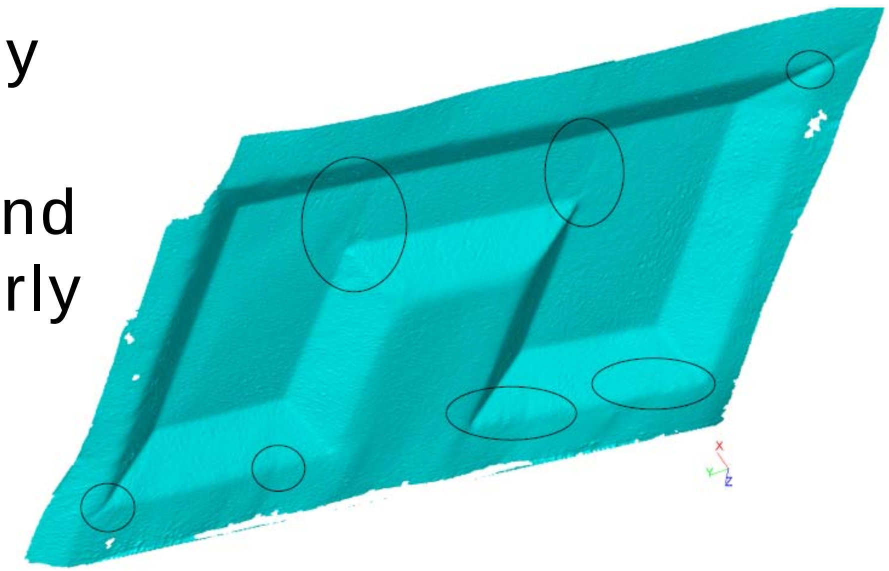
- Example of investigation of mapping the inspected lay-up thickness against the design data, to identify defects and anticipate laminate quality before cure.
- What is being mapped is any deviation from the expected ply stack thickness at each point in the lay-up
- We need to understand how variations in incoming materials or in process impact on expected ply stack thickness



Experimental verification 2

- For more complex structures such as the sandwich panel shown here the starting point has to be a very clear understanding of the expected route to drape as that controls both local thicknesses and the regions in which defects are likely





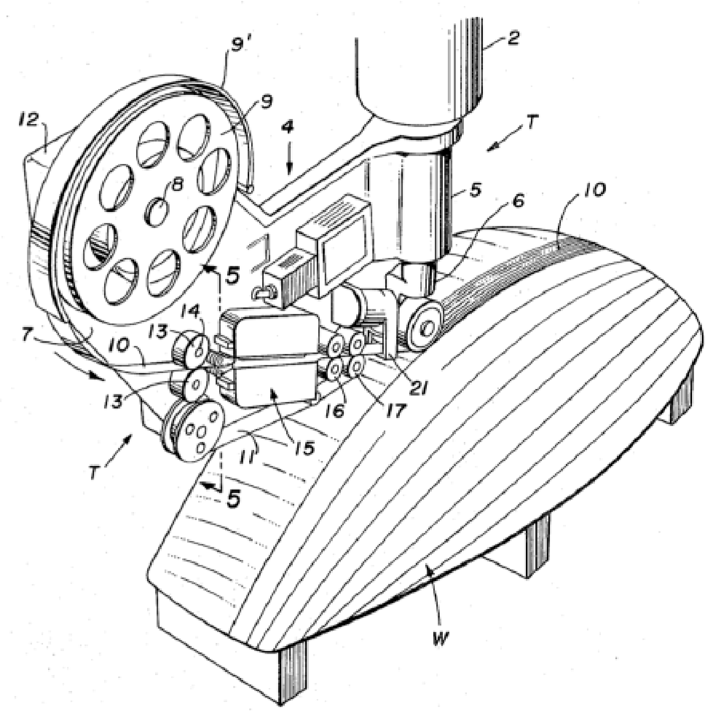
- Defects such as fibre wrinkling and bridging in internal radii are clearly visible in the scanned surface

Next steps

- The work to date has demonstrated the feasibility of using techniques such as the T Scan, and other forms of scanning are being investigated for other manufacturing routes than hand lay-up
- Scan rates need to be significantly improved to fit in with a production drumbeat – although if debulk cycles are used that might offer a scanning point with minimal cycle time impact
- The critical challenge is probably not acquiring the surface data as such but the integration of that data with design data and incoming materials variability data to distinguish between variability and defects

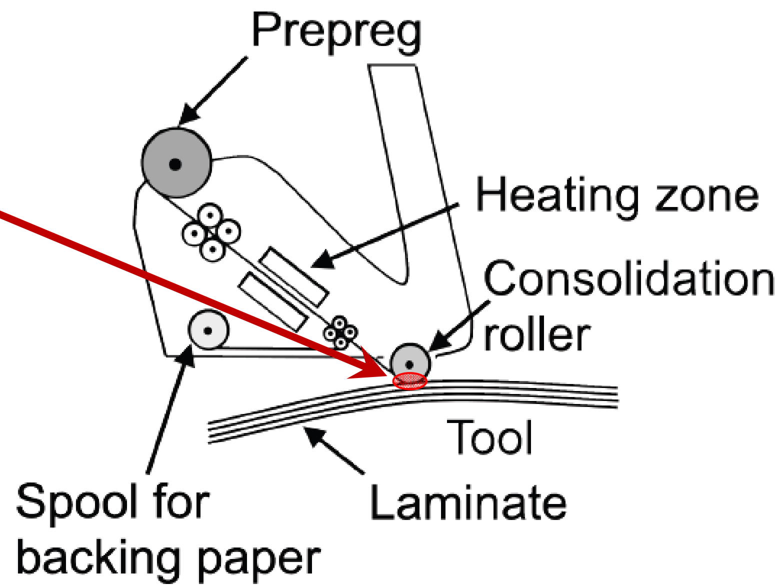
Fundamentals of the tape laying process

- Tape laying and automated fibre placement machines are critical to the development of high quality large parts at high production rates
- The technology development dates back to the late 1960s
- 40 years on from the original patents there is still not a very large installed base of these machines around the world (Compared to CNC metal cutting which has about a decade longer history)
- Equally there is a relatively limited research base for these machines



Impacts on Quality and Costs

- To a first approximation the quality of the cured part in terms of performance-critical factors such as voidage depends on the as-laid quality off the ATL machine
- De-bulk cycles are not generally used in ATL production so the importance of achieving the best quality at the point of fibre lay-down cannot be overstated
- The interaction of materials and machine at the tiny footprint of the consolidation roller is crucial.
- Current machines run at ~ 1m/s, leading to a very short interaction time, which may get even shorter as machines continue to develop

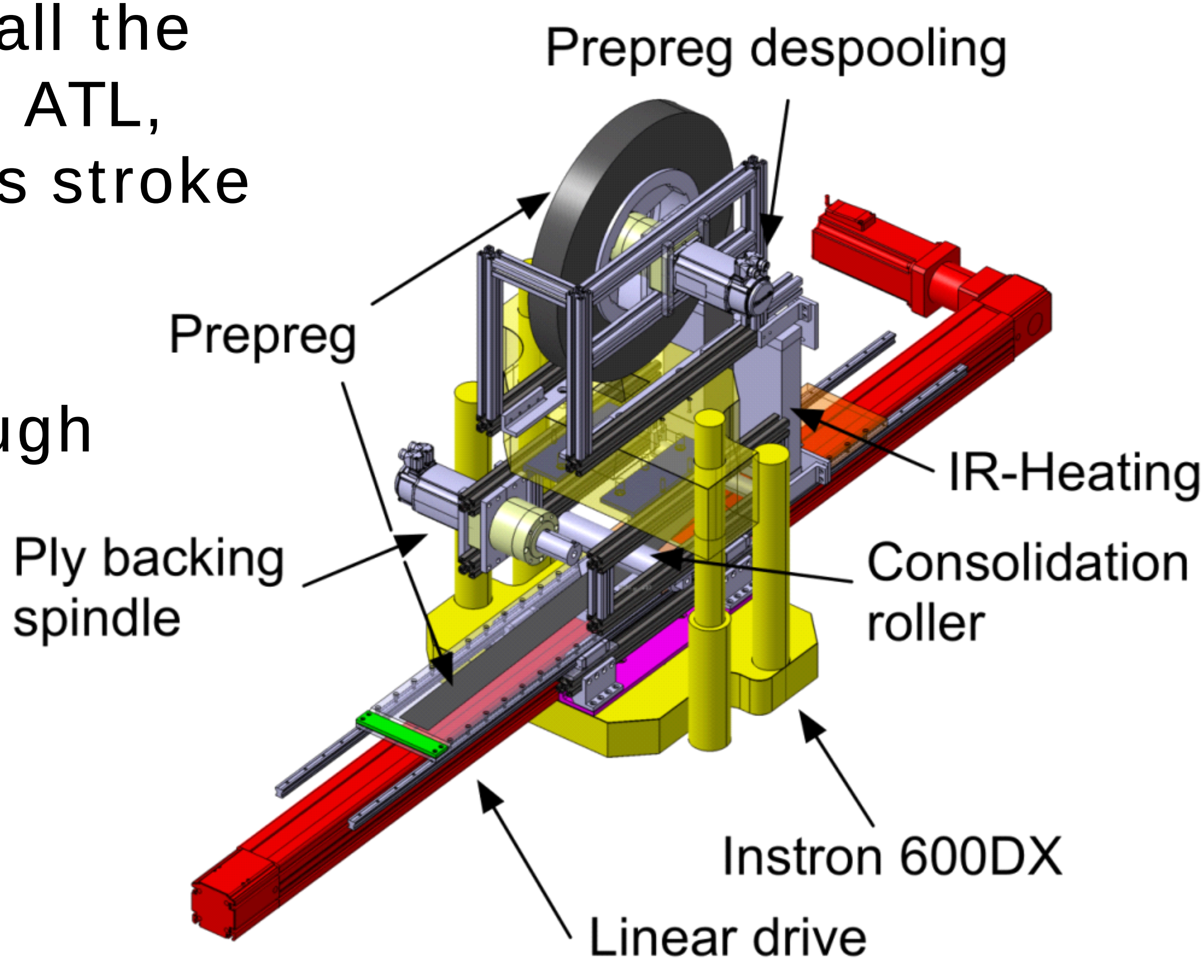


How can we research these issues?

- A commercial ATL costs £millions and in any case is generally run at its maximum production rate
- Even if they could be afforded, commercial ATLs are not very suitable for research into the consolidation process due to limitations on heating, control, data collection and instrumentation and traverse speed
- To overcome these issues a simulated ATL head has been designed and is approaching completion

Simulated ATL head

- The simulated head has all the features of a commercial ATL, but the machine operates stroke by stroke rather than continuously
- Loads are captured through the use of an Instron load frame
- IR heating prior to the stroke allows close temperature control over a wide temperature range
- The stroke rate is 2m/s rather than the 1m/s on most ATLs



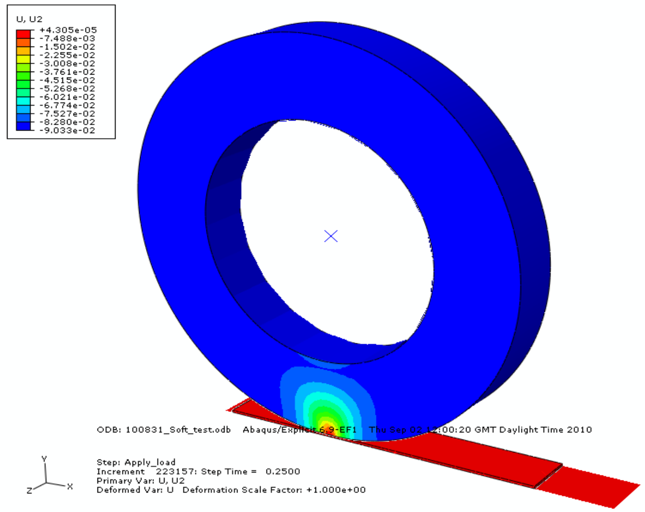
Materials Characterisation and Modelling

- We need to understand the mechanical response of the prepreg to the conditions at the point of lay-down
- We need to understand the variability in prepreg mass/unit area and resin content, surface roughness, internal air entrapment and other material properties
- A model of the lay-down process is in development and can help to
  - Optimise lay-down conditions
  - Design improved machinery and prepreg materials
  - Maximise the quality of the manufactured parts
  - Increase productivity without introducing defects

Next steps

- Validate the model using the simulated ATL head
- Include tack and friction into the model
- Extend to a non-isothermal model
- Extend model to a wider range of prepregs
- Model layup over complex geometries

Soft roller model



Centre for Innovative Manufacturing in Composites

Aims for the EPSRC Centres for Innovative Manufacturing

- Create, deliver and disseminate world-leading research
- Address major long-term manufacturing challenges/and or emergent manufacturing opportunities
- Provide strong support for UK manufacturing industries
- Enhance the global profile and significance of UK research
- Create a National network of expertise in manufacturing knowledge
- Outreach to other centres and relevant research groups

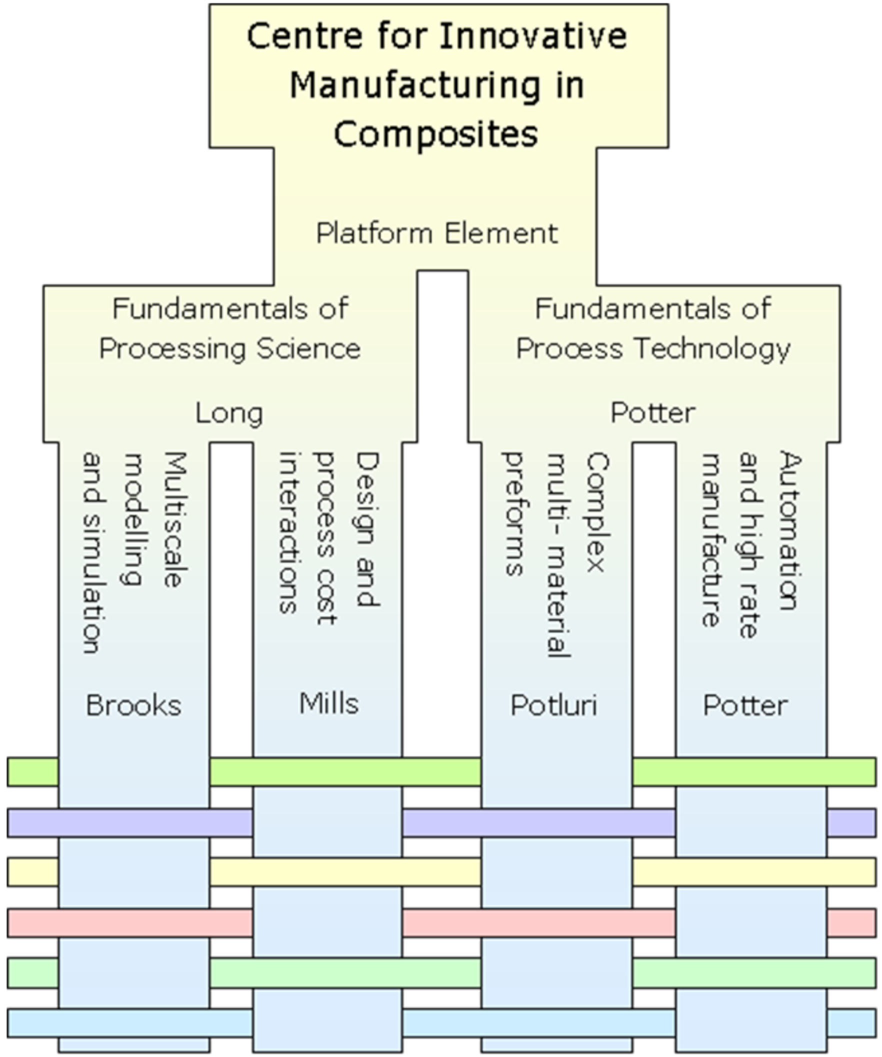
EPSRC requirements for the level of business/user direction and support

- EPSRC is asking for
  - Cash and in-kind support from users
  - Evidence the bid is co-created with users
  - Evidence Director has a track-record of collaborating with users
  - Management strategy to ensure user-relevance

- EPSRC's expectations
  - Users would be the key users in the scientific area
  - Cash and in-kind support would be appropriate for user and sector
  - It would be really clear to the Panel from the case for support that the bid was co-created with users
  - Advice from users would be appropriately used in decision making
  - Strategy to grow user engagement in terms of funding and numbers of users

Current status

- Nottingham, Bristol, Cranfield and Manchester are collaborating in a £6million bid, to be led by Nottingham
- The vision is to bring together a strong team of researchers with considerable industrial experience and weave together and integrate their skills to drive forward the fundamental understanding of composites manufacturing and its practical implementation



Next steps

- The shape of the proposal is essentially known, but the details are still open to industrial input and a short outline can be made available to any interested organisation
- To get involved as a supporter of the proposal please contact Andrew Long or myself in the first instance
- The proposal will have to be essentially complete by the 30th of September so there is limited time to influence the details of the proposal
- If we are successful in acquiring the funding a wider engagement with the industry will be a feature of the Centre and there will be further opportunity to interact with it as it develops.