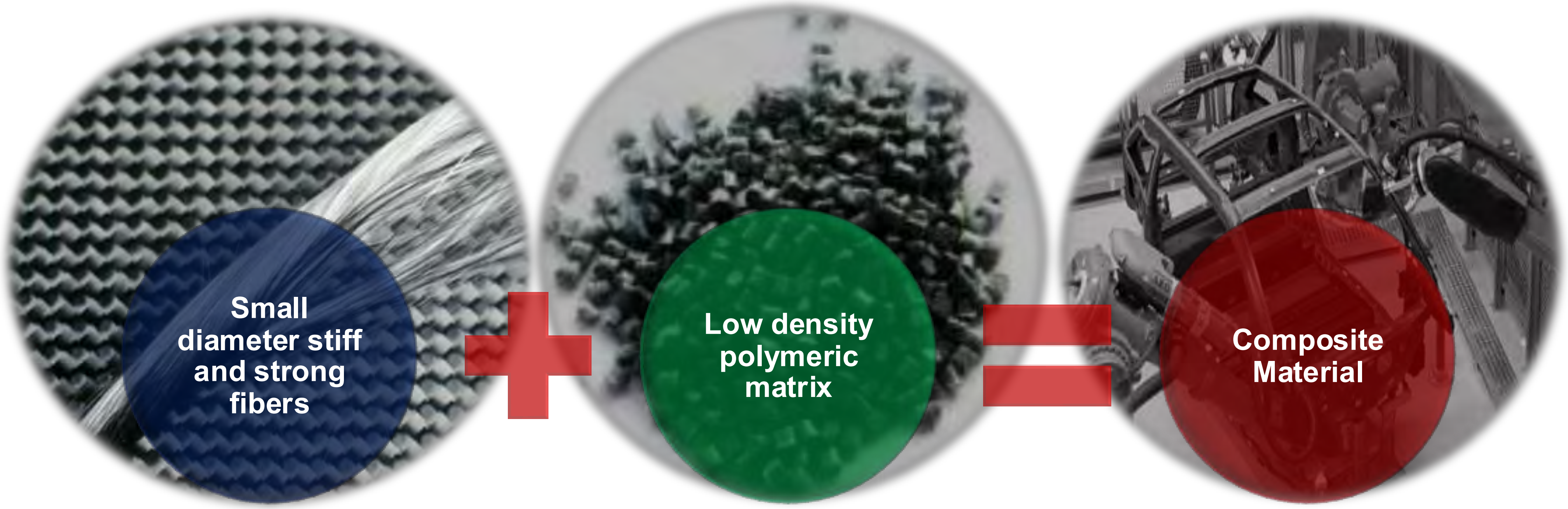
Composite materials combine complementary substances



For properties not present in the individual components

Circular composites?

V. Michaud
LPAC

25 November 2024

École polytechnique fédérale de Lausanne

EPFL

Laboratory for Processing of Advanced Composites

LPAC Laboratory for Processing of Advanced Composites

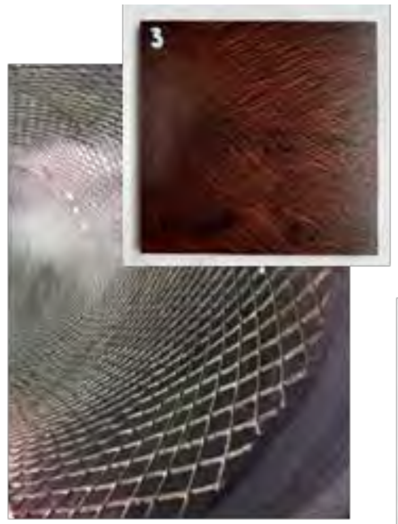
Fundamentals of composite and hybrid materials processing

Cost-effective and environmentally sustainable functional materials and structures.

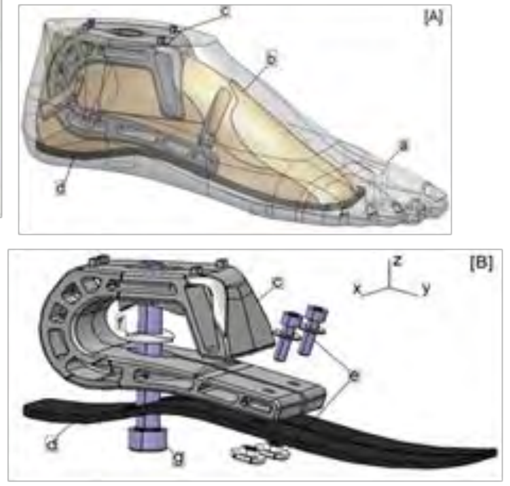
Applications: transport, energy, sport, food and bio-medical fields.

Relevant topics to the SDGs:

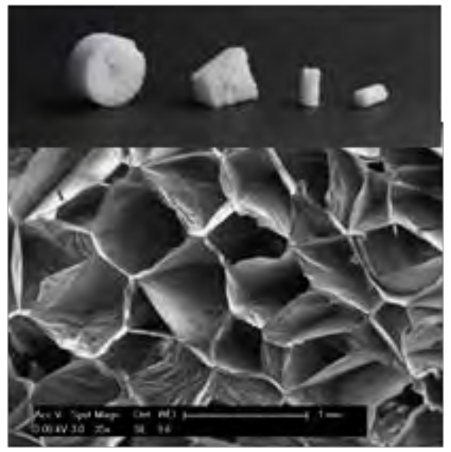
- Health and wellbeing (Prosthetic foot, low power new-born incubators, biodegradable composites & hydrogels for medical applications, recycled 3D printed PET for assistance devices),
- Responsible consumption and production (bio-based fibers and composites, low energy manufacturing routes for composites, nanostructured surfaces for waste reduction, self-healing composites),
- Climate action (light weighting, integration of solar panels, composite recycling, cost and LCA, design for de-misability in space applications, lower embodied energy materials, decarbonization modelling).



Palm fiber composites, Flax Power Ribs (Bcomp)



Agilis project: prosthetic foot below 80CHF



Bio-degradable foams for medical applications

Bio-sources polyesters Recycled PET for 3D printing

Synthetic yellow rose petal surface with pepper grains contamination

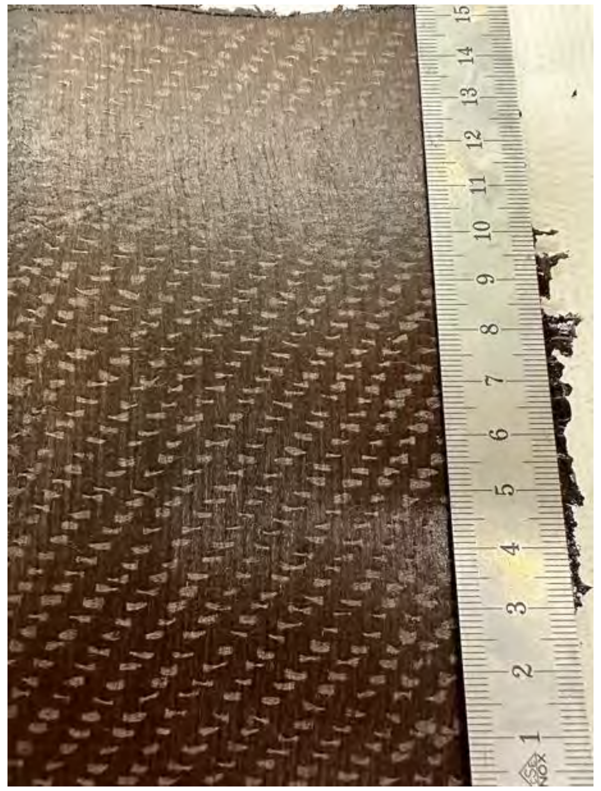
Circularity in/with composite materials ?

- Today: composites <10% circular, behind metals
- Historical parts: disassemble, sort, recycle, re-use constituents, while keeping structural properties.
- Future: opportunity to change current materials/processing methods/design concepts
- A key material: needed where properties reduce use phase impacts (lighter weight, more energy efficient concepts, design flexibility…)
- Expanding markets: energy generation (wind turbine blades), transport (H_2 vessels, new generation aircraft, battery trays..) and industrial applications.

LPAC – lower embodied energy materials

coll. Luterbacher group

- **Alternative fibers:** from cultivated natural sources (flax, hemp, jute), and from agricultural waste (rice husk, coffee husk, banana plant leaves)
- **Alternative resins:** from bio-based sources (tannins, biobased resins), bio-attributed, or more recyclable systems (vitrimers, reactive thermoplastics)

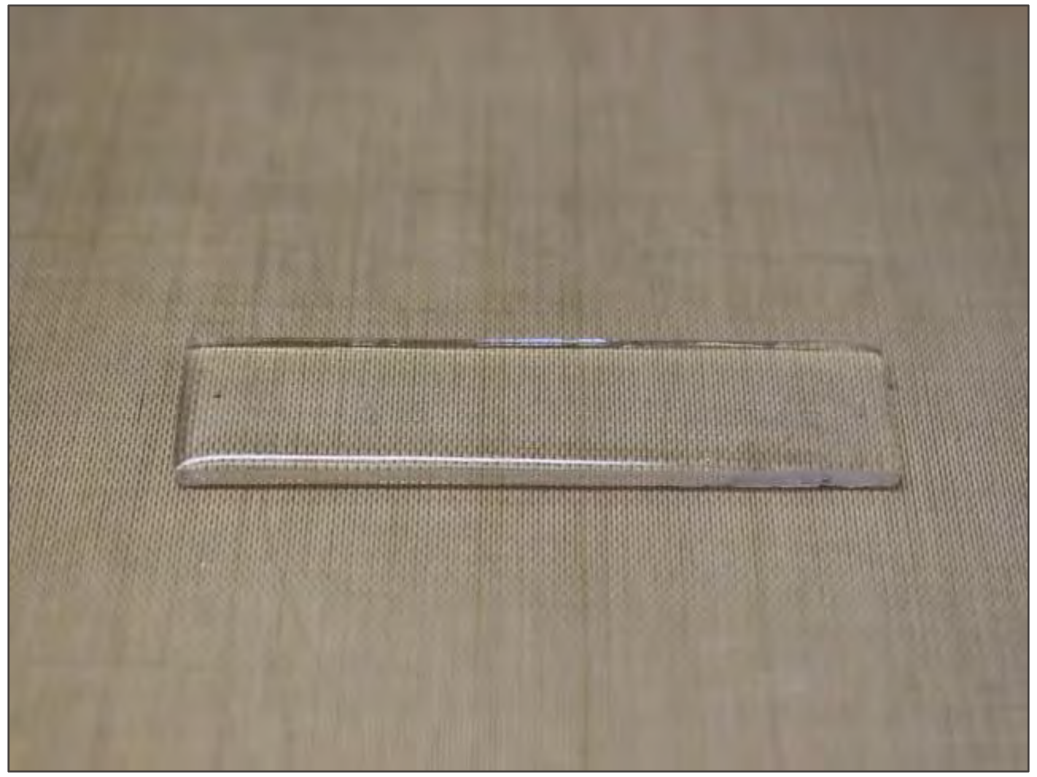


Tannin/Banana leaf, or Flax (G. Fokam, coll. ENSPY, BFH)

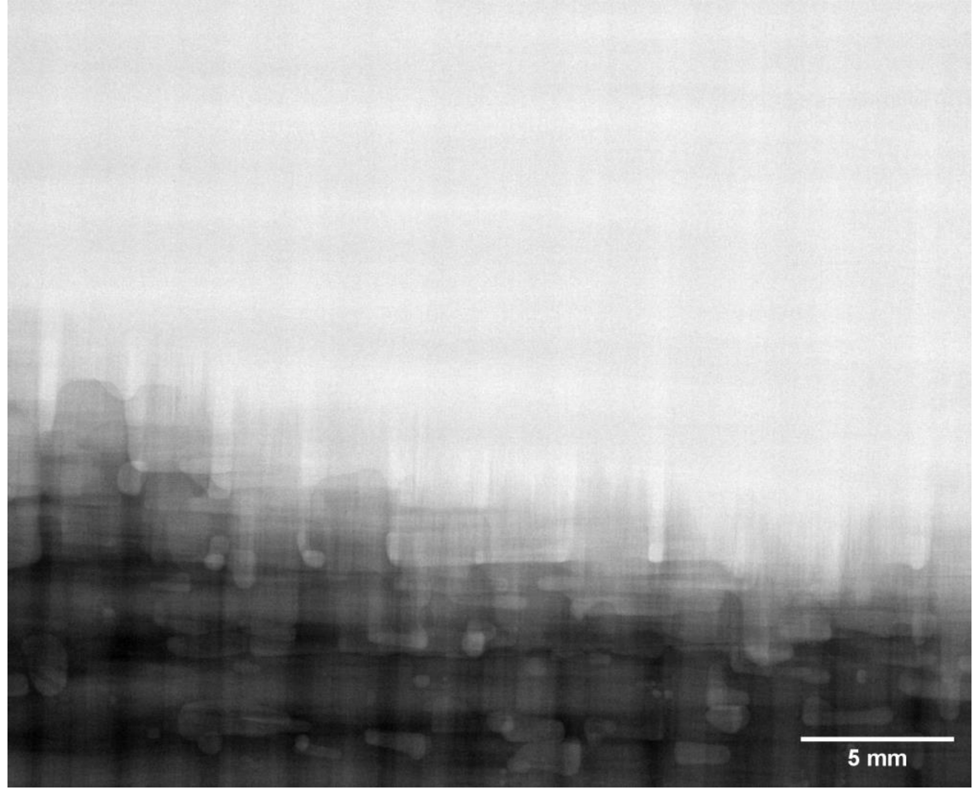
Manicaria palm fiber/Elium (M. Morales, J. Porras, coll. Los Andes)

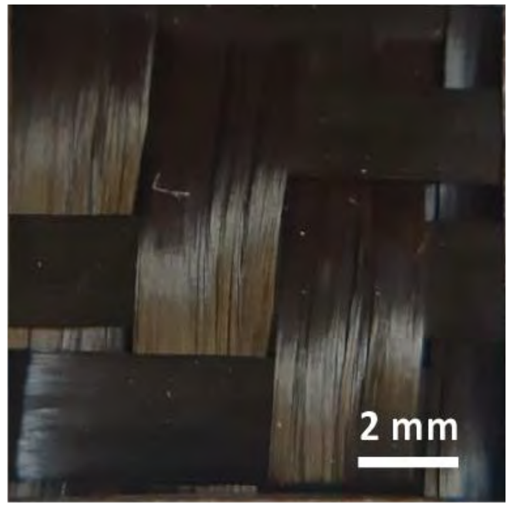
LPAC – lower energy processes

- Out-of-autoclave processes (lower energy/ reduced CAPEX)
- Low energy curing (UV curing, frontal polymerization)

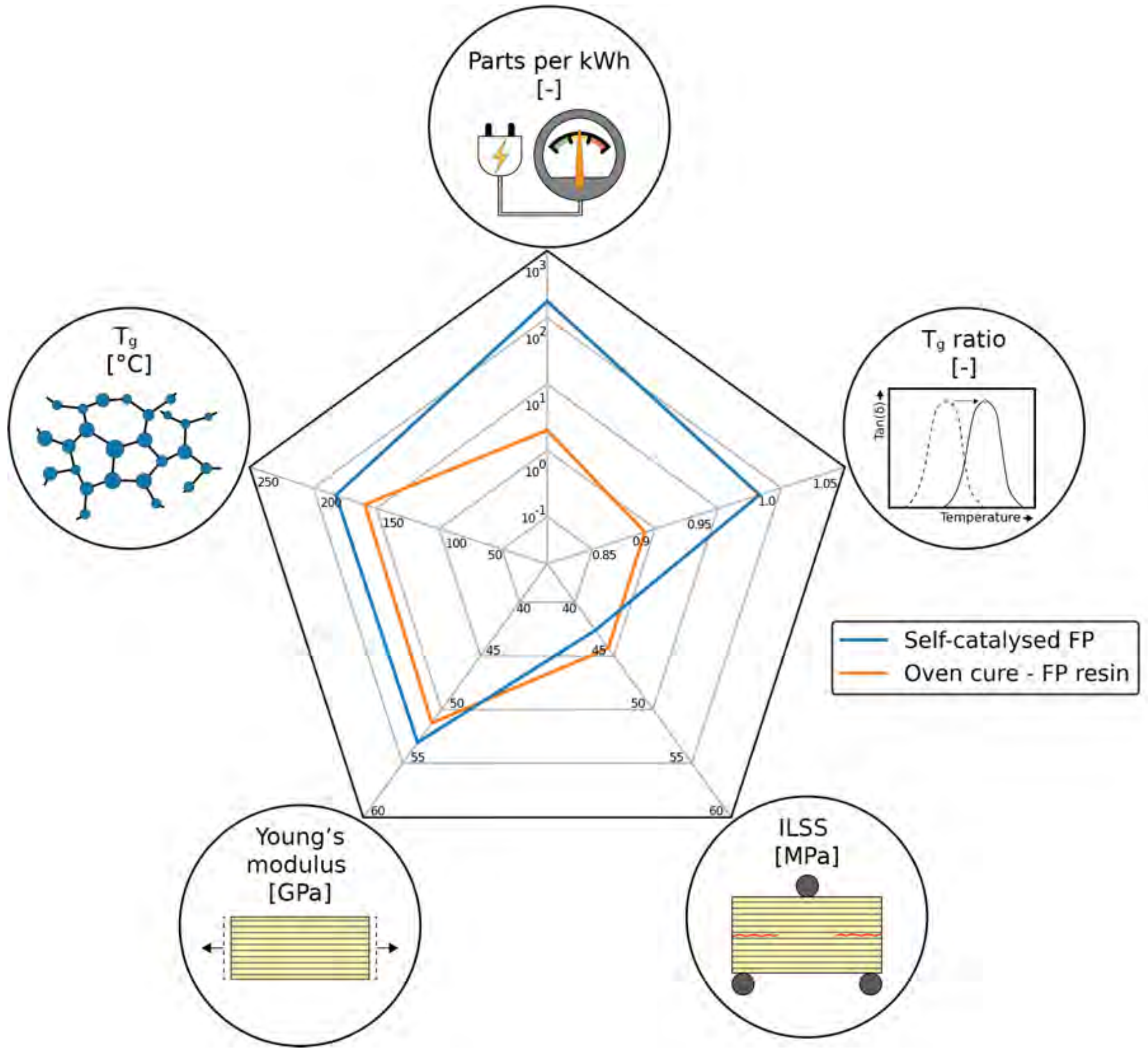


Frontal polymerization of epoxy-acrylate gel (J.Staal)



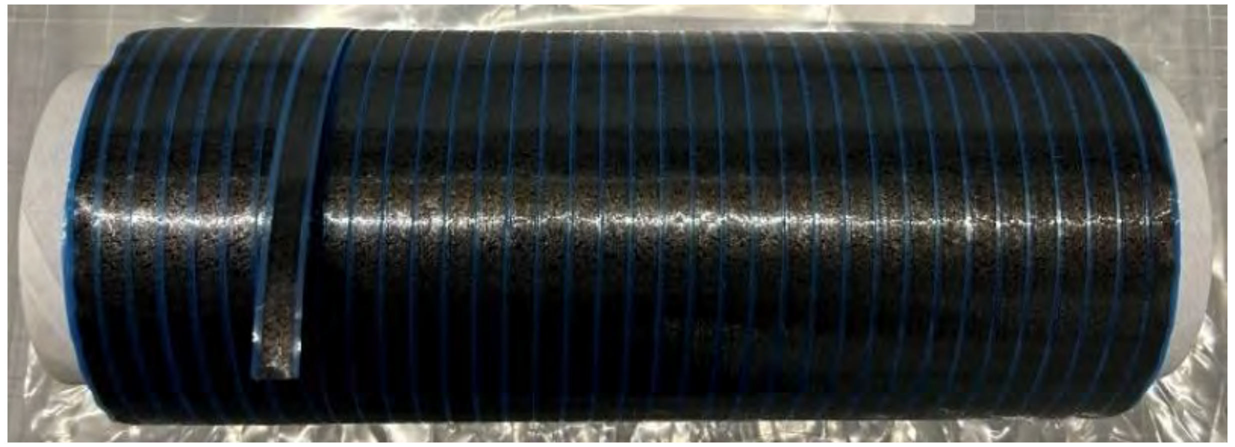


Fundamental understanding of flow based processes (H. Teixido)



LPAC/FIMAP – lower waste / functionalized

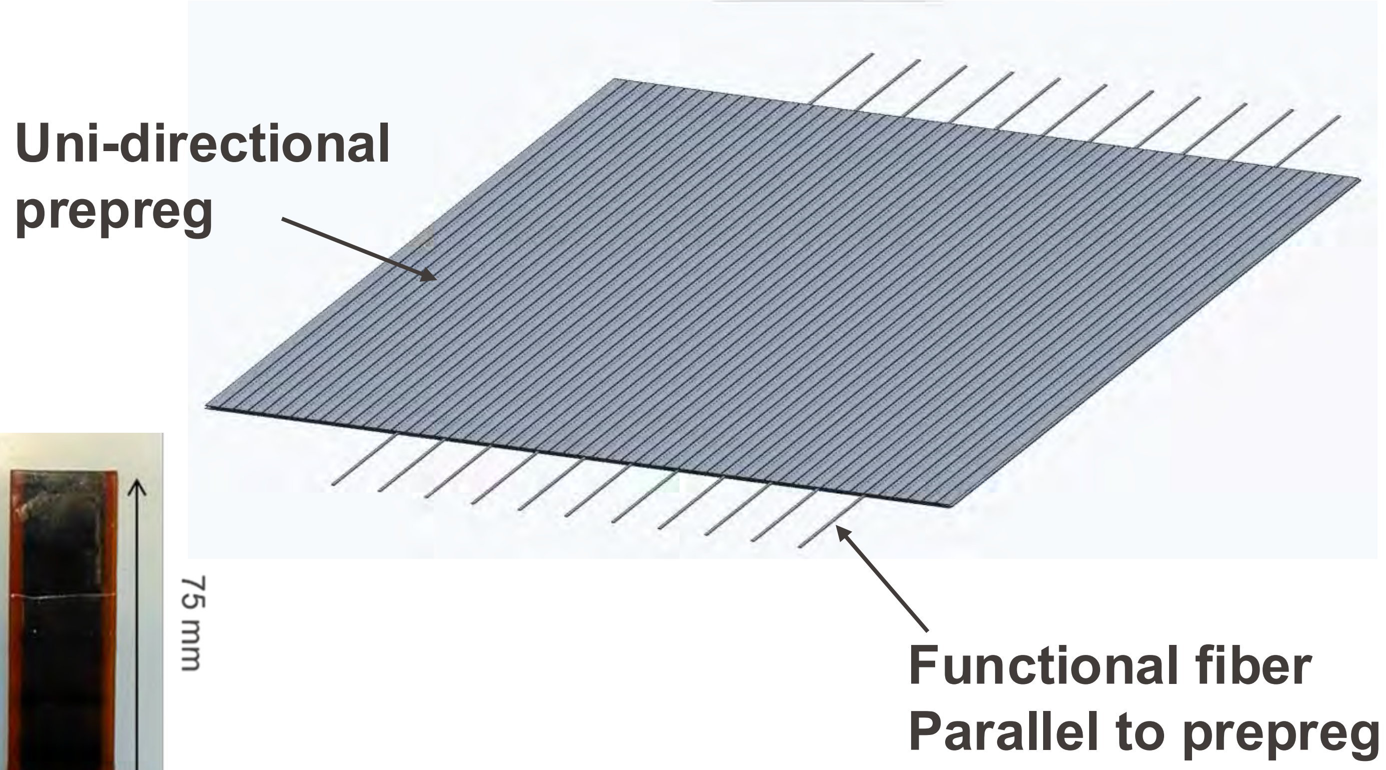
- Integrated sensing in composites (multi-functional)
  - Temperature, strain, (haptics, humidity)
- Produced using 6-axis / 8-axis robot
- Prolong life time (durability)
- Reduce waste

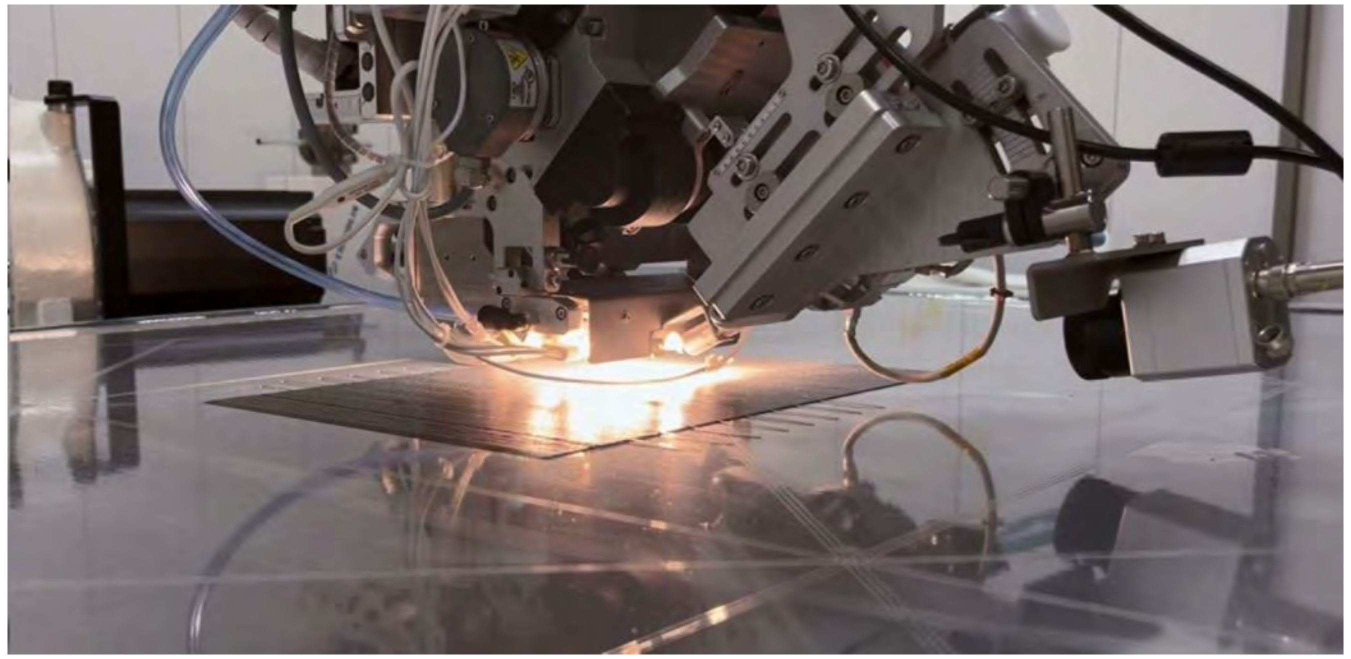


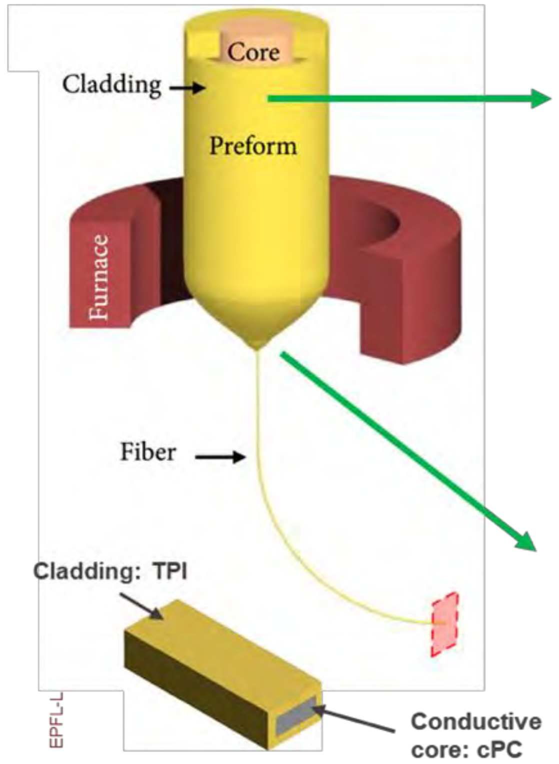
LPAC
Composites structure

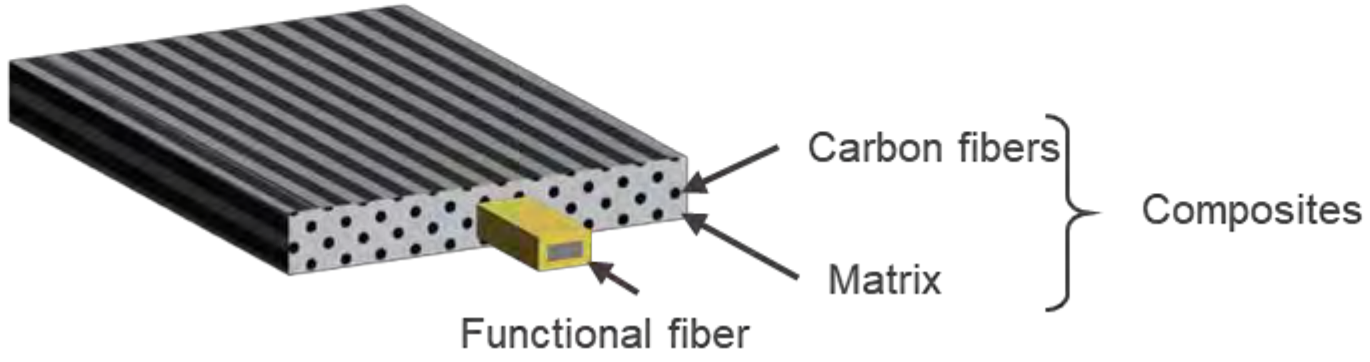
CORIOLIS
Industrial additive manufacturing

FIMAP
Multi-material functional fibers



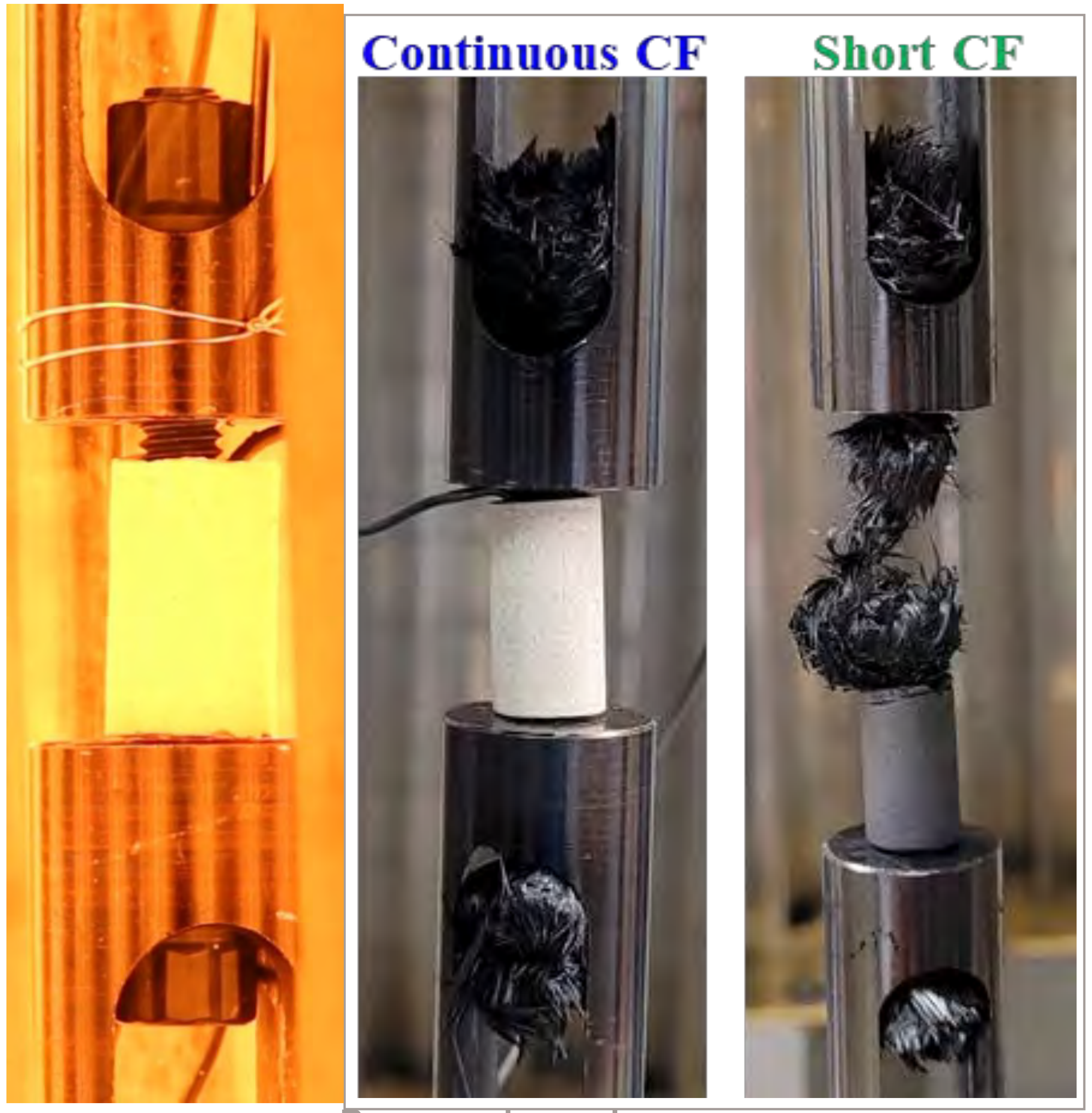






LPAC – overall life cycle approach

- Self-healing composites (CompPair Technologies SA)
- Composite recycling (collaboration with CR)
- Net-Zero scenario projects (Flagship project, E4S project)
- Design for de-bonding/demise (Use of de-bondable adhesives, demisable composites for space applications)



Recovered samples

Demisable composites upon reentry after orbit (A. Looten)

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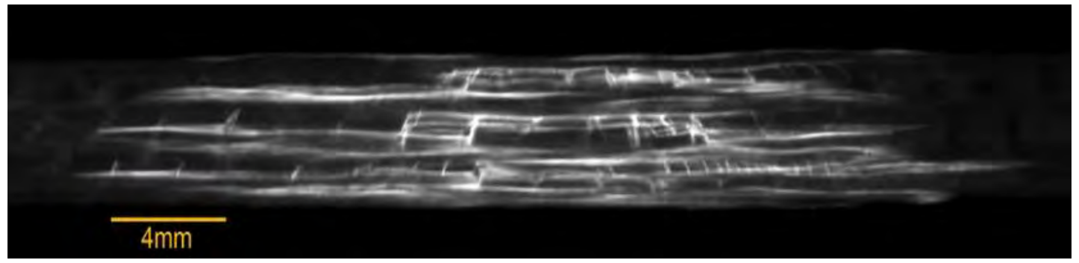
Self-healing composites

V. Michaud

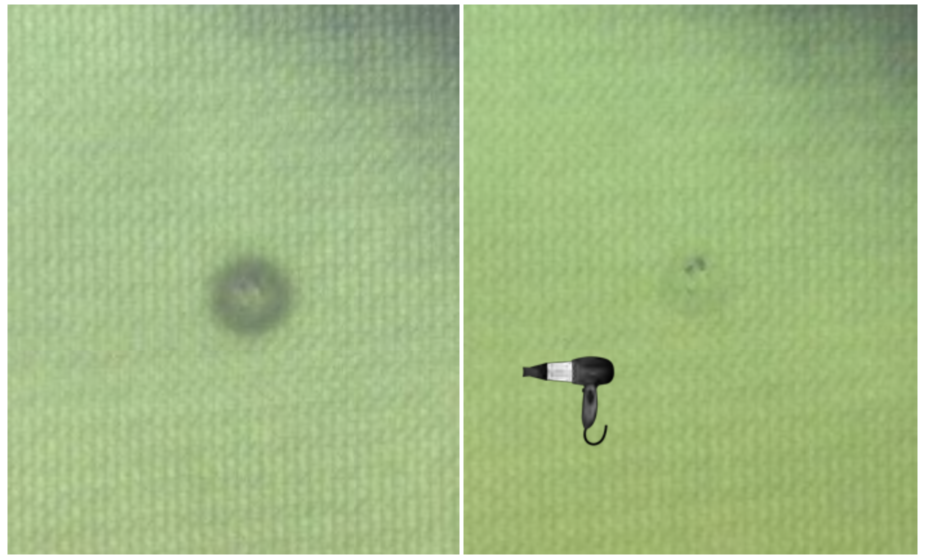
- Improve part reliability, durability and "frugality" through better design, better manufacturing with less safety margins
- Improve part life through on-site repair and remanufacturing
  - Use of thermoplastics or vitrimers for potential reprocessing
  - Use of debondable adhesive concepts for reuse/separation of layers
  - Use of self-healing materials

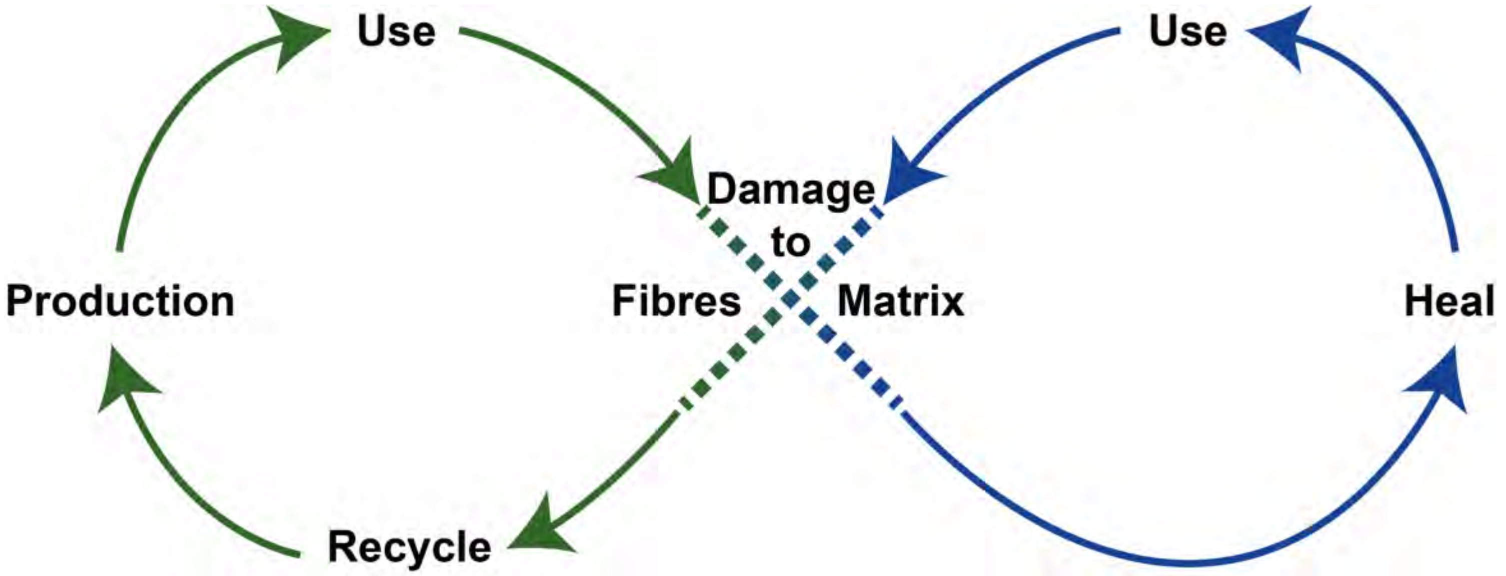


5J impact, from Gaille 2005

After impact

After healing





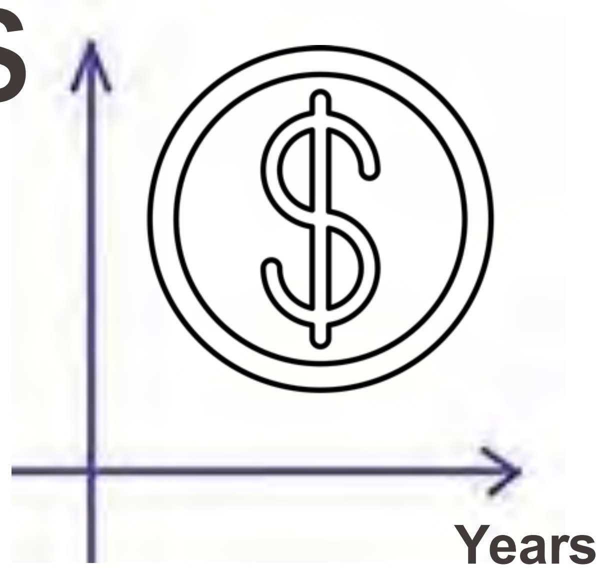
COMPPAIR

LPAC - Decarbonization modelling

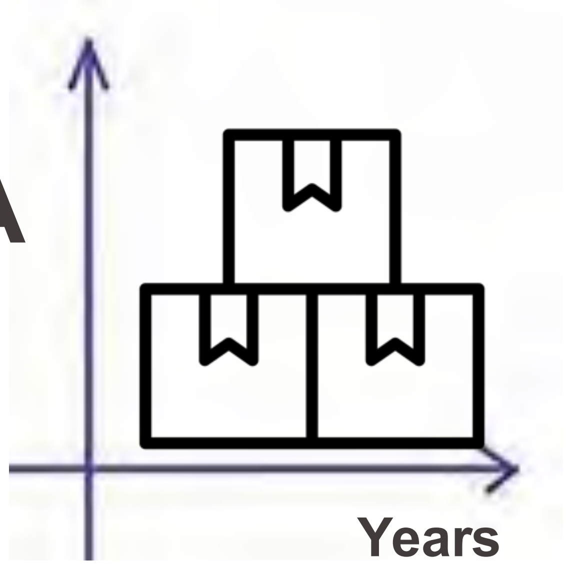
- Market growth to 2050 versus Supply
- Key technological enablers
- Lower embodied energy Carbon fiber
- Grid mix used
- Post industrial waste treatment
- Degree of circularity and end of life
- Quantified sustainability strategies and road maps

Monte Carlo model, tracking

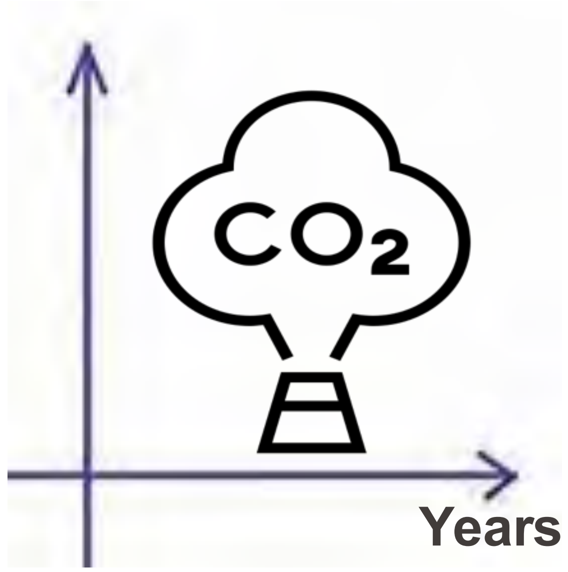
Monetary $



MFA



CO_2e



E4S Enterprise for Society

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

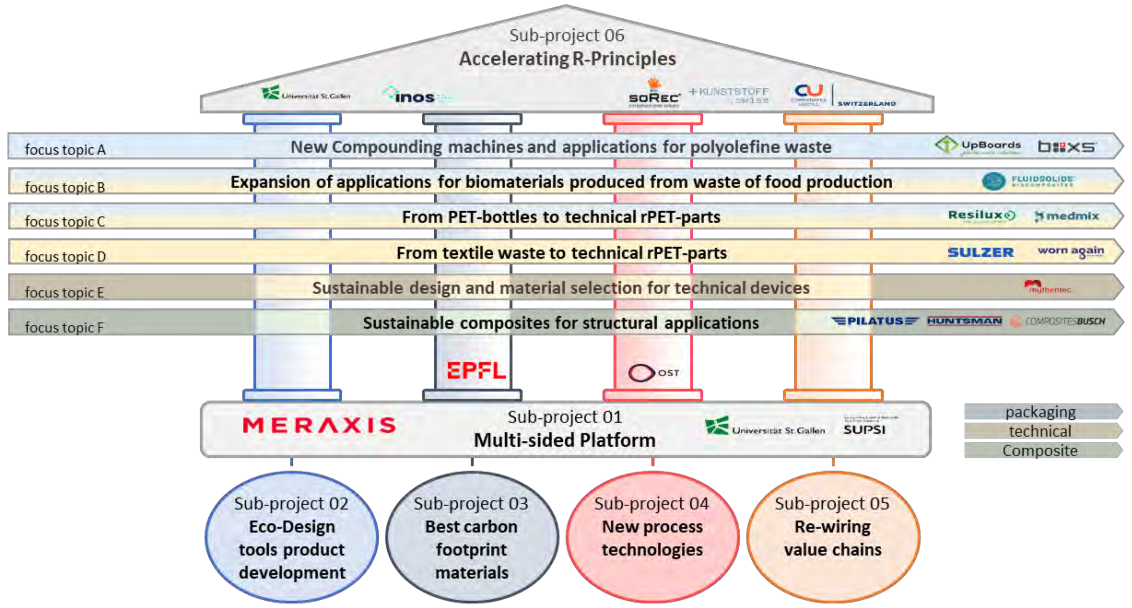
Swiss Confederation

Innosuisse – Swiss Innovation Agency

Best carbon footprint materials

Towards a NetZero Plastics Industry

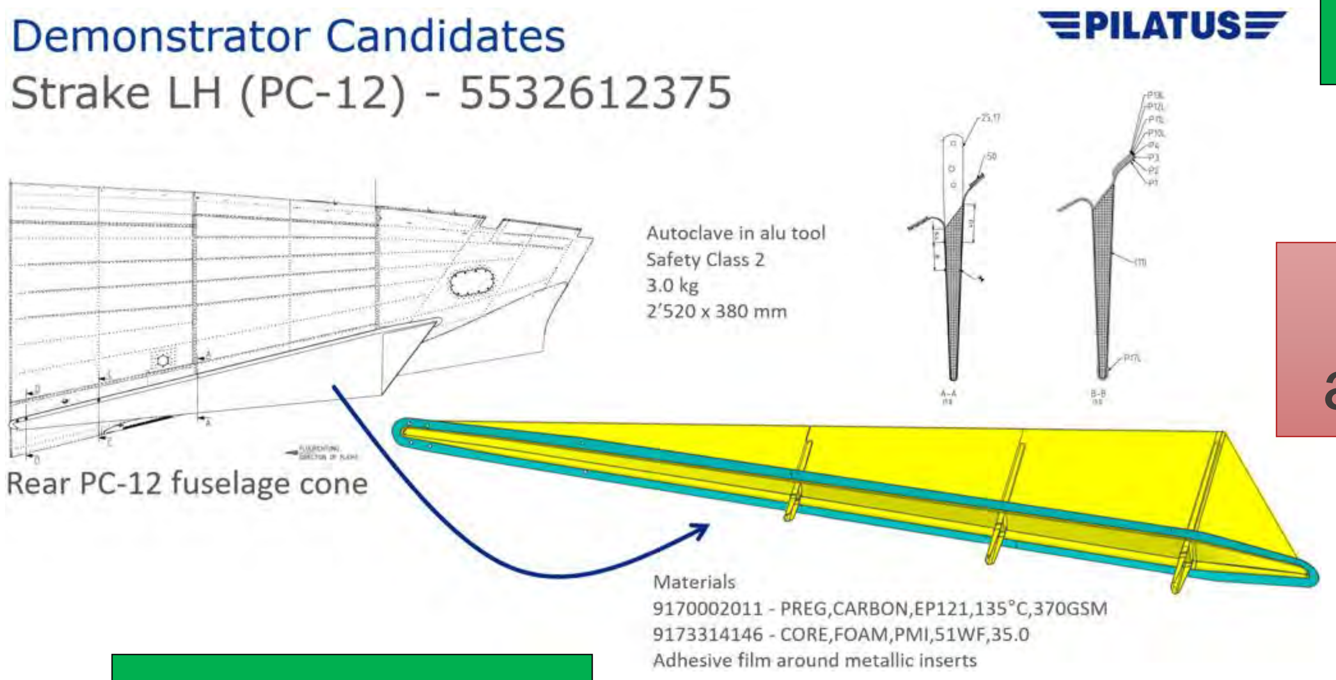
18 companies, 5 research institutions, 3 associations



- Focus Topic F composites
  - Re-wire current linear CFRP supply chain to circular models
  - Reduce CO_2e in the supply chain and develop NetZero 2050 roadmaps
  - Develop best carbon footprint materials and test in demonstrator component (Pilatus)
  - Demonstrate CFRP traceability and circularity with subsequent fiber and matrix recovery and re-use in 2_{nd}ary part
  - Quantify system wide benefits (LCA) across scope 1, 2, 3 and generate SMART sustainability initiatives

Focus Topic – F Team

PILATUS, HUNTSMAN, Composite Recycling, COMPOSITESBUSCH, OST, LPAC Laboratory for Processing of Advanced Composites



Novel materials

Primary application

Recovery / recycling / reuse

Secondary applications

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Conclusions

- Supply chain collaboration
  - integrated consortia
  - from materials to semi-finished products, to part final production and the use phase to end of life and circular scenarios …
- We cannot do this alone, better together!
- Need to find good ways to quantify the impacts…for this, data availability/ measurement/ curation is key.
- And possibly new business models (producers responsible for use phase…)

"I'm well aware of the problem. I'm working on it."