Multi-Functional Materials Towards Environmentally Friendly Aviation

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ECATS

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CHALMERS

CONTENTS

INTRODUCTION

Motivation

- Pressure for use of hybrid or electrical vehicles is becoming higher.
- Several European countries are setting ambitious goals.
- Norway is targeting for 2030 forty percent of all short distance sea ships to use biofuels or be low or zero emission.
- In the frame of the ACARE 2050 vision, **Airbus has committed to cut emissions by 50%.**
- **Airbus aims at offering zero emission aircraft by 2035**

Heart Aerospace, electric regional aircraft ES-19, range 250 miles, planned entry into service; 2025

- High volumes of energy will have to be stored on the aircraft.
- **More need than ever to be innovative in terms of weight**

MULTI-FUNCTIONAL MATERIALS

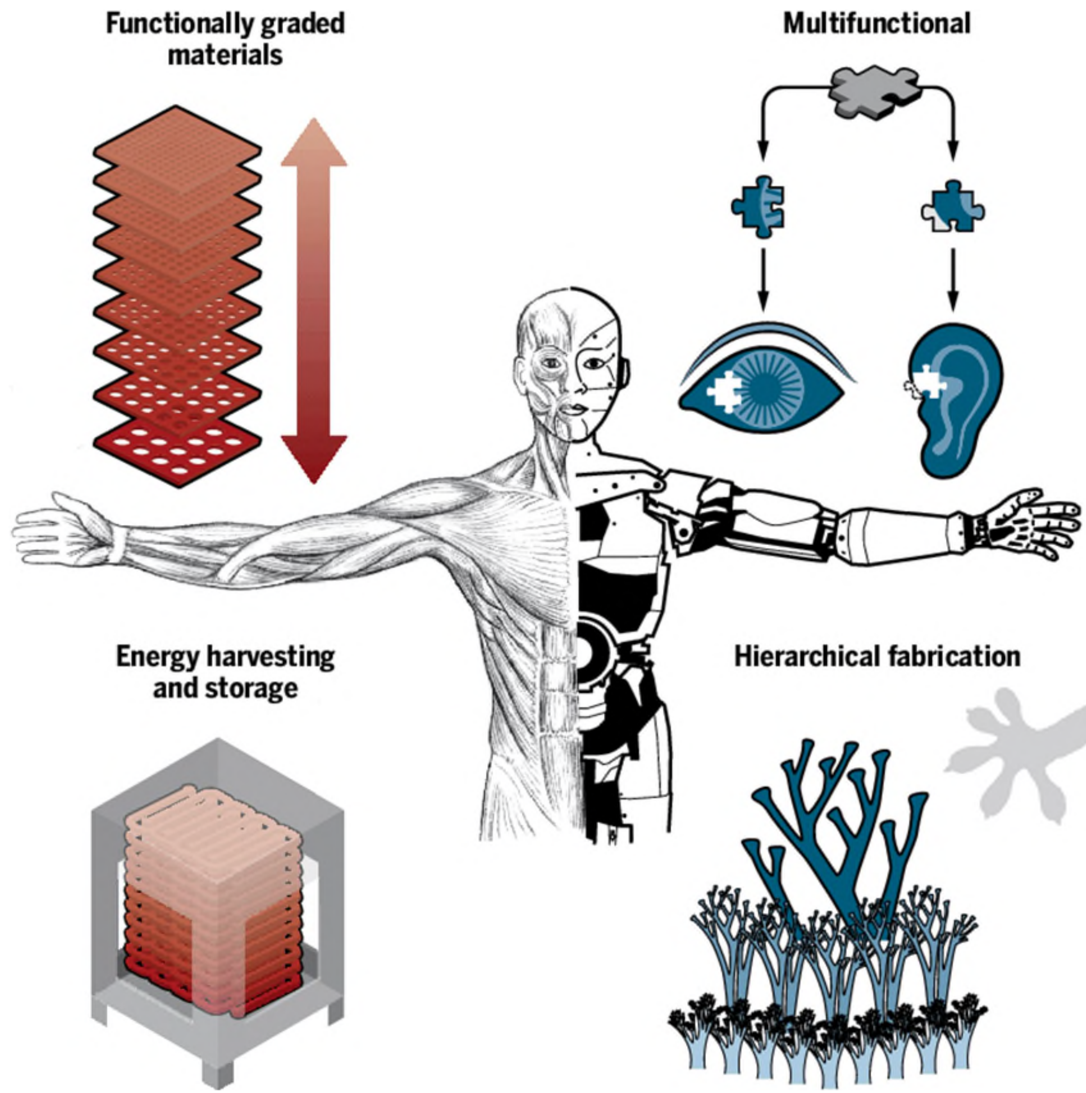
Most efficient machines found in nature.

Most organs in a human body fulfill more than one purpose:

Example: muscles; provide:

strength, stiffness, movement

They can: extend, contract, convert energy, self-heal



STRUCTURE INTEGRATED DATA AND POWER

CURRENT SITUATION

Electrical harnesses are currently made up of bundles of cables, which are manually assembled on rigs and integrated into the fuselage

- **Harnesses are assembled in a very labour intensive process**
- **Thousands of brackets are used for attachment of harnesses**
- **Amount of electrical wiring increases with every new program**
- **Immense cost for late changes**
- **Bundles incorporate highly diverse cable types**
- **Path optimization of cables created complex, branched bundles**
- **Design of structure has be reinforced around cable ducts**
- **Connectors are bulky and outdated – high effort for certification impedes improvements**

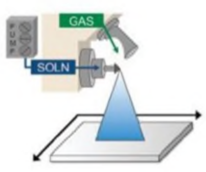
STRUCTURE INTEGRATED DATA AND POWER

Technology Overview: electrical functions integrated within structural materials

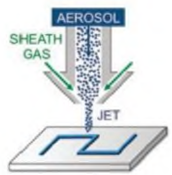
Process

Non-Contact Printing | Contact Printing | Alternative Methods

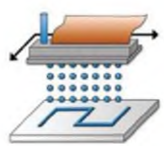
Cold Spray



Aerosol Jet



Inkjet Printing



Roll-to-Roll Processing

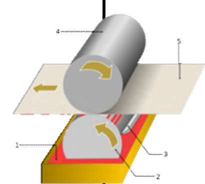
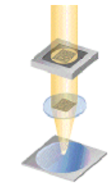


Photo-lithography



Substrate

3D geometries

- Aircraft Components

Flexible Sheets (2D)

- Paper
- Polymer
- Glass
- Silicon

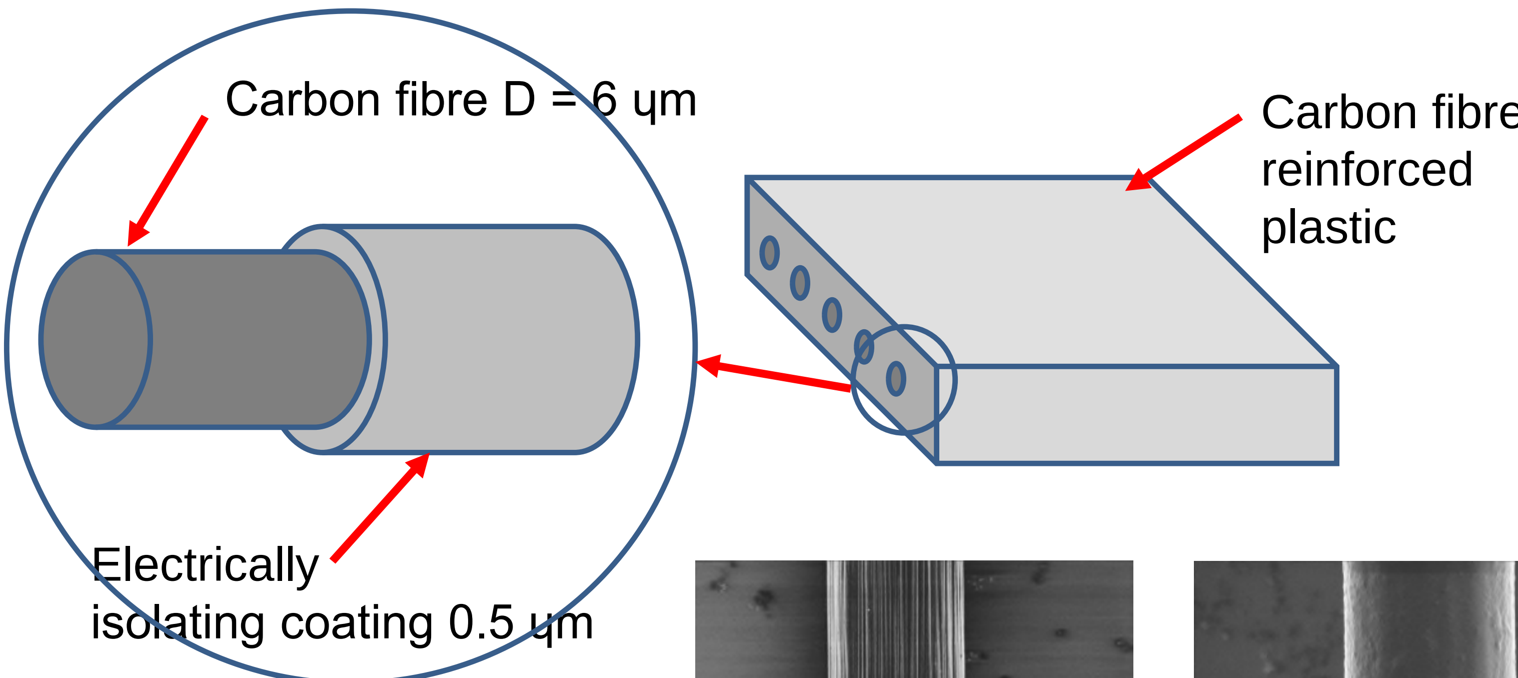
Inks

Nanoparticle | Metal | Carbon nanotube/ graphene | Conductive polymers | Metal-organic | Catalyst | Reaction inkjet system

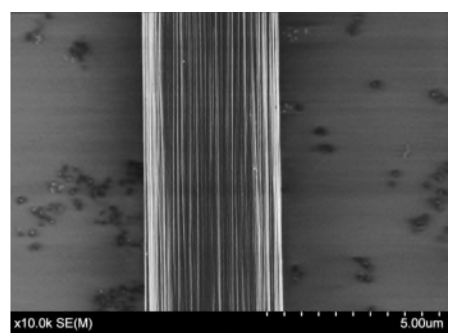
STRUCTURE INTEGRATED DATA AND POWER

Integrated data transmission by multi functional carbon fibre with electrically isolating coating in structural composite

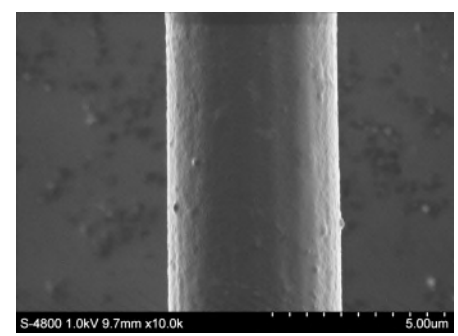
Peter Linde, Leif Asp, Dan Zenkert, Airbus Patent Award Winner, March 2017



Master Thesis in preparation
by Maximilian Schutzeichel
Hamburg Univ. of Appl. Science



Uncoated carbon fibre



Coated carbon fibre

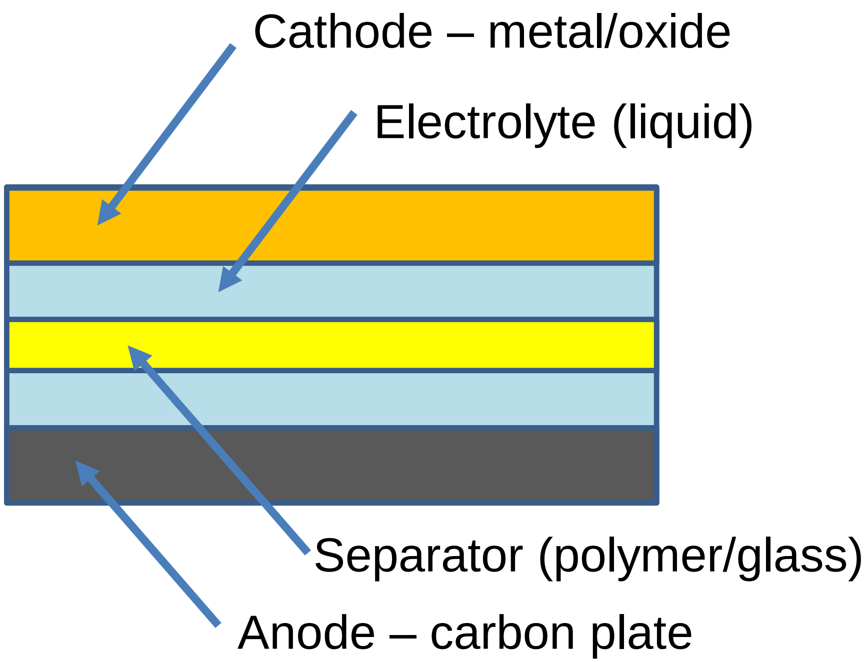
STRUCTURE INTEGRATED ENERGY STORAGE

How?

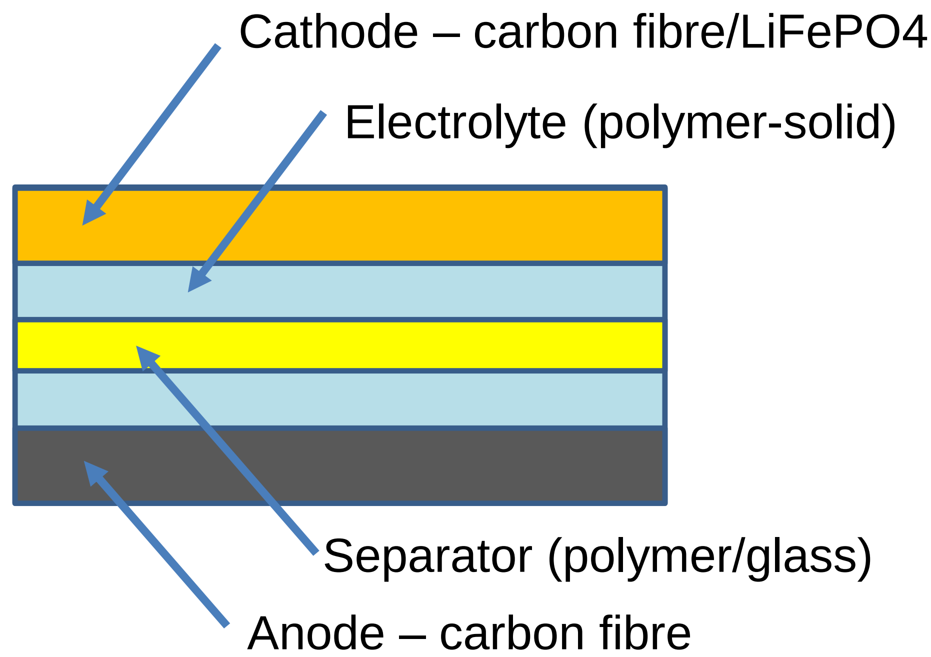
- There are two ways for integrating structures and batteries,
  - **Storing the energy in the structural material.**
  - **Enabling the battery casing to carry other structural load path on top of its own weight.**
- The first one works with the structural material chemistry, improving its electrical properties, enabling it to store energy.
- The second one take a conventional battery and changes its physical design to make it part of the aircraft structure.

Courtesy: Prof. Emile Greenalgh et al, Imperial College of London

STRUCTURE INTEGRATED ENERGY STORAGE



Li-ion (liquid electrolyte) battery

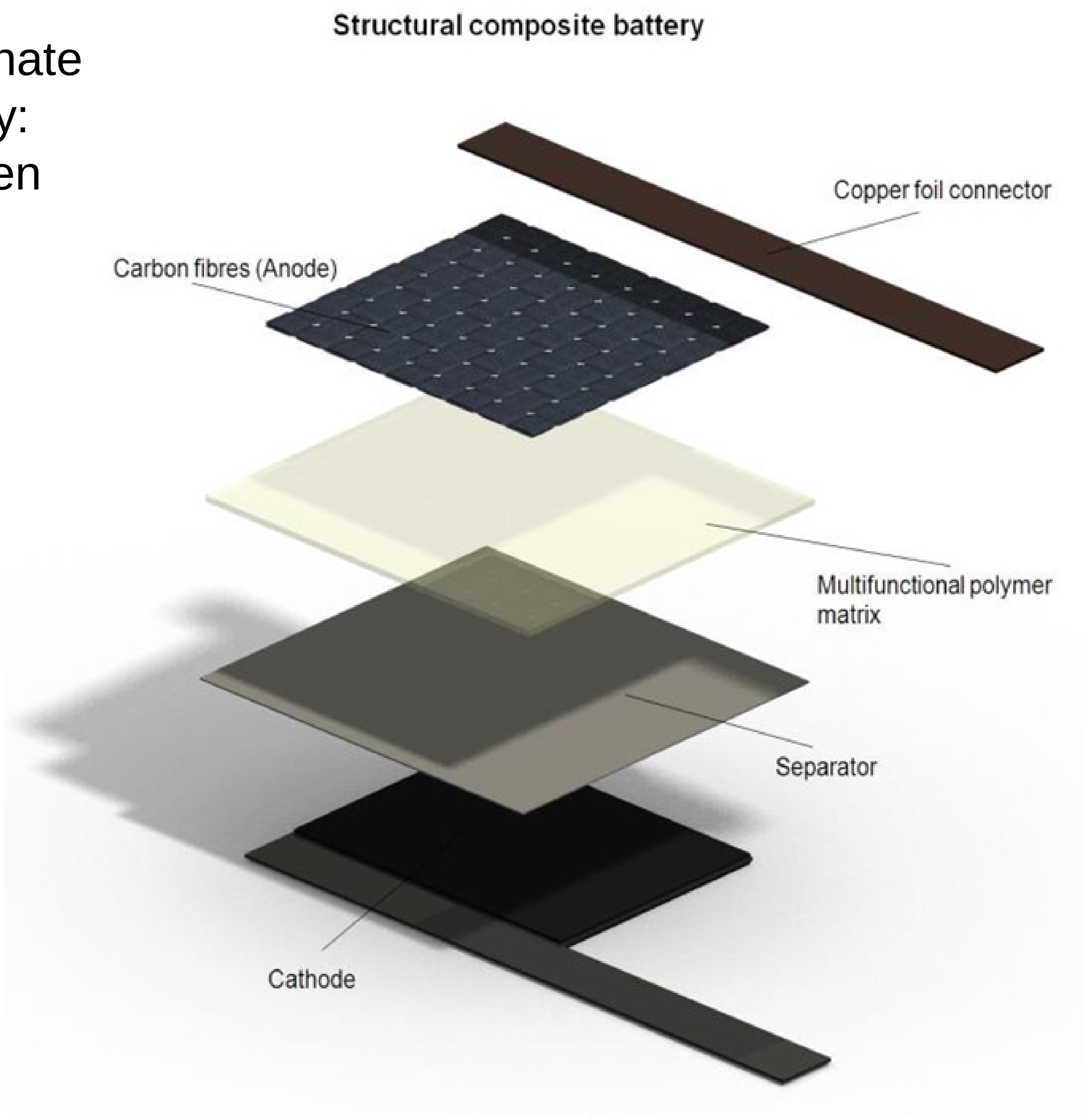


Carbon composite laminate (solid electrolyte) battery

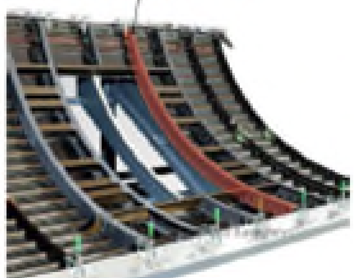
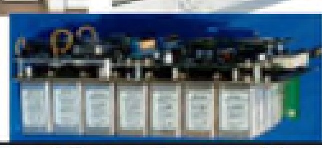
INTRODUCTION

Composite laminate structural battery: SICOMP, Sweden 2008

Early work:
Sofia Ekstedt
Maciej Wysocki
Leif Asp

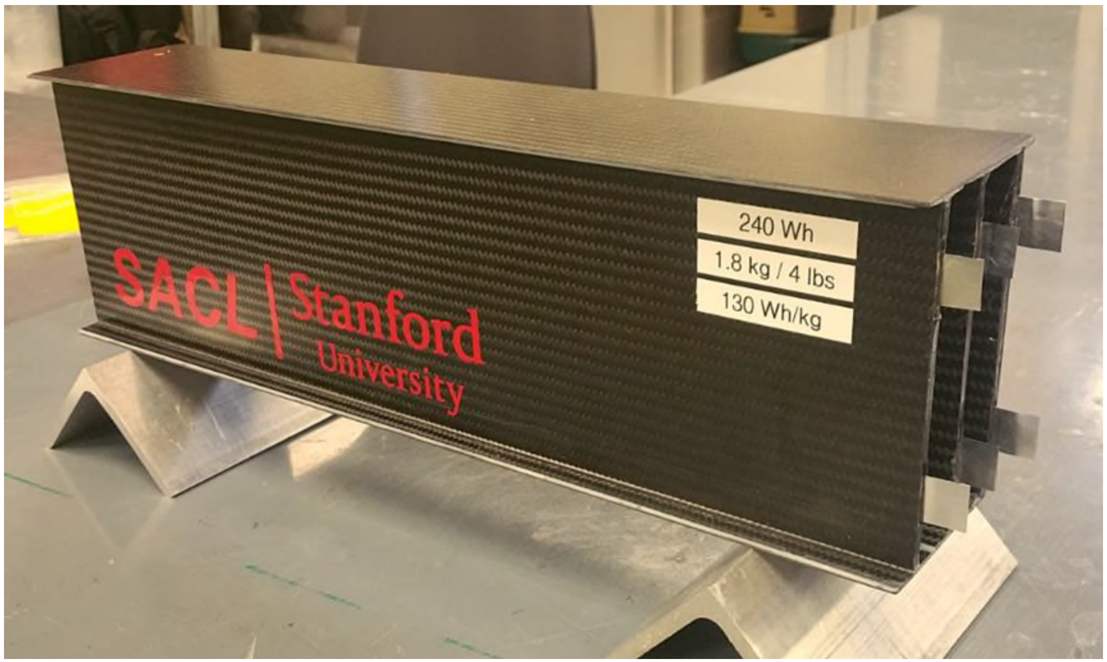


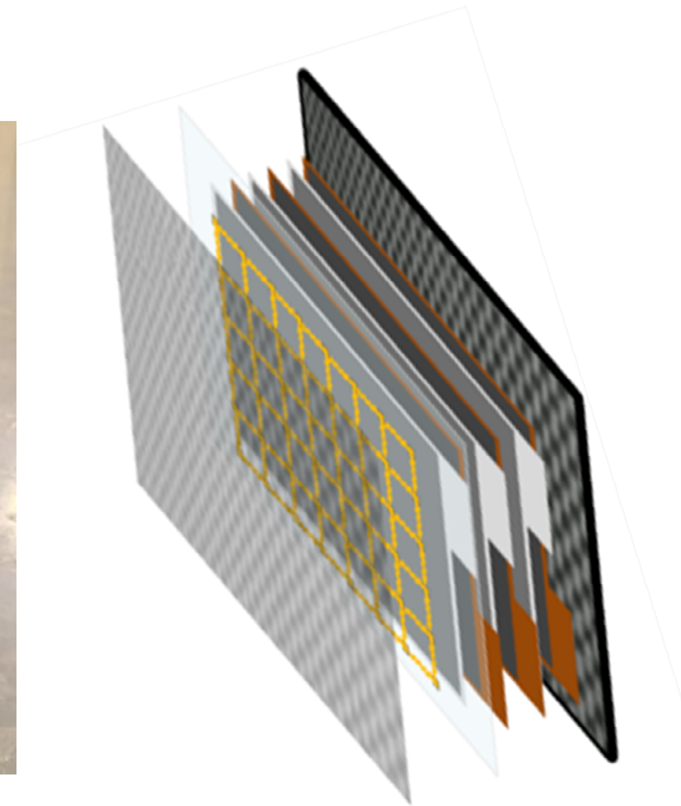
STRUCTURE INTEGRATED ENERGY STORAGE

Demo #	Component (*Device*)	Description	Aircraft Architectural Domain & Aims
1	 Cross-beam (*Structural Battery*)	• Section of cross-beam (support of the cabin floor) without access holes. • I-beam section, CFRP.	*STRUCTURE/MATERIAL* • Integrated battery as structure. • Match mechanical stiffness of existing monofunctional component, as assess weight penalty associated with structural power. • Characterise structural behaviour.
2	DEPS (*Structural Supercapacitor*)   	• Local Door Controller is a back-up power system for the 16 A380 passenger doors. Ultracapacitors are used as reliable backup power system. Opens independently of the main electrical system. Required momentum: 800-900 nanometers • Input power: 130VA @ 28VDC • DC Output: 60A and 6A • Standyby: 8 hours • 400 x 230 x 140mm • 4.2kg	*SYSTEM* • Integrated structural supercapacitor in CFRP door structure (adopting part of DLR door frame demonstrator). • Demonstrate for 'comfort opening' of Door in Airbus Door Demonstrator, for operation of electric door opening motor. • Characterise structural behaviour and functionality.
3	PSU (*Structural Battery/Structural Supercapacitor*) 	• Full colour CLEDU with PoD interface. Option for connecting single colour illumination devices without control electronics	*CABIN* • 28Volts DC • Integrated battery (reading lights) with integrated supercapacitor (latch for oxygen masks) • Characterise functionality. • Tentative business case compilation, including simplified power cable installation.

Clean Sky 2 project SORCERER

STRUCTURE INTEGRATED ENERGY STORAGE



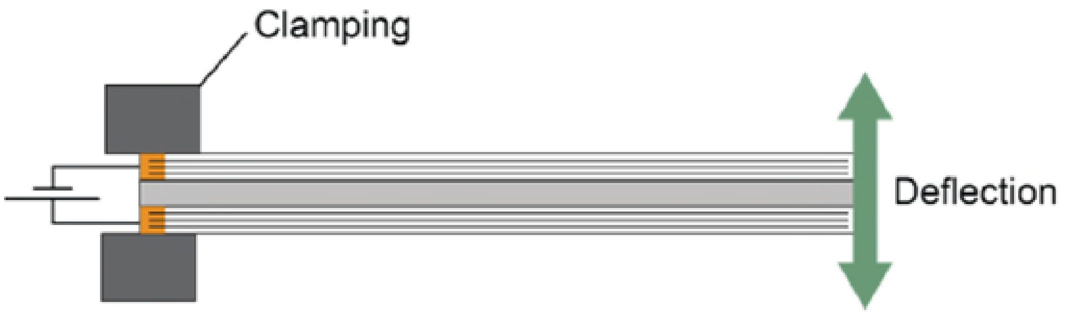


Multifunctional structure battery: Carbon fibre reinforce plastic casing, with li-ion cells attached inside. Source: Prof. Fu-Kuo Chang, Stanford University, 2018

DERIVATIVE FUNCTIONS

Lithiated carbon fibres (in structural battery); able to contract and expand, with degree of lithiation:

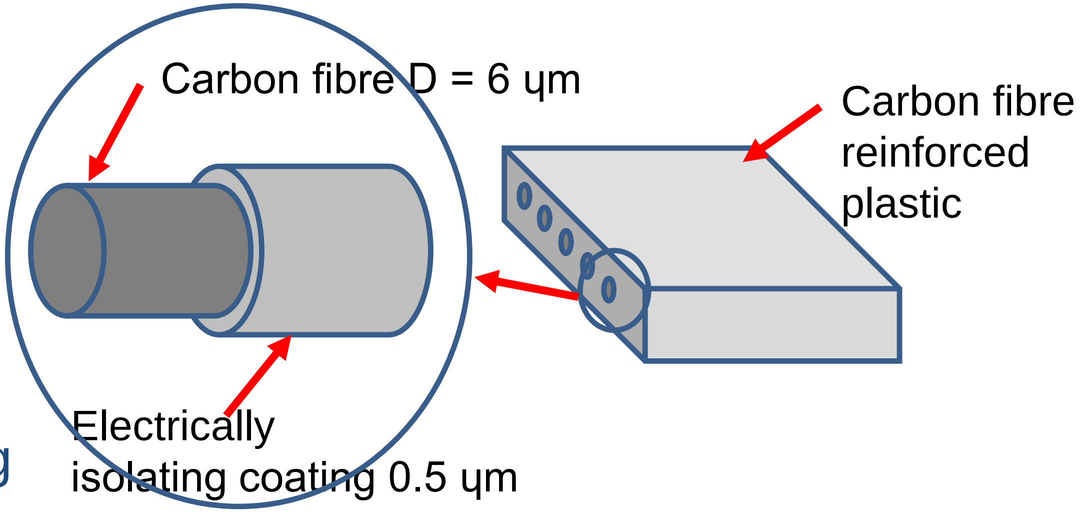
- morphing material (if lithiation changed)
- energy harvesting (if motion imposed, e.g. vibration etc.)



Morphing beam with lithiated carbon fibres. Source; Dan Zenkert, KTH

Carbon fibres coated with electrically isolating polymer coating:

- -heat transmitting (Joule effect) ->
  - welding,
  - anti-icing
  - morphing
- Sensor
- flight physics (shock bump)
- Electro magnetic shielding



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- Prof. Dan Zenkert, Royal Institute of Technology
- Prof. Emile Greenalgh, Imperial College of London
- Engineering colleagues at Airbus Operation GmbH

SUMMARY

- **Pressure from authorities and from environmental aware public force us to develop more envirmentally friendly transportation**
- **Multi functional materials transport vehicles can help save weight and energy**
- **Integration of data and power into structure well on its way**
- **Integration of electric energy storage is in its beginnings, some different, parallel concepts are on their way, enabler for el.flight**
- **Many further functions are recently discovered and await investigations**

THANK YOU FOR YOUR ATTENTION!