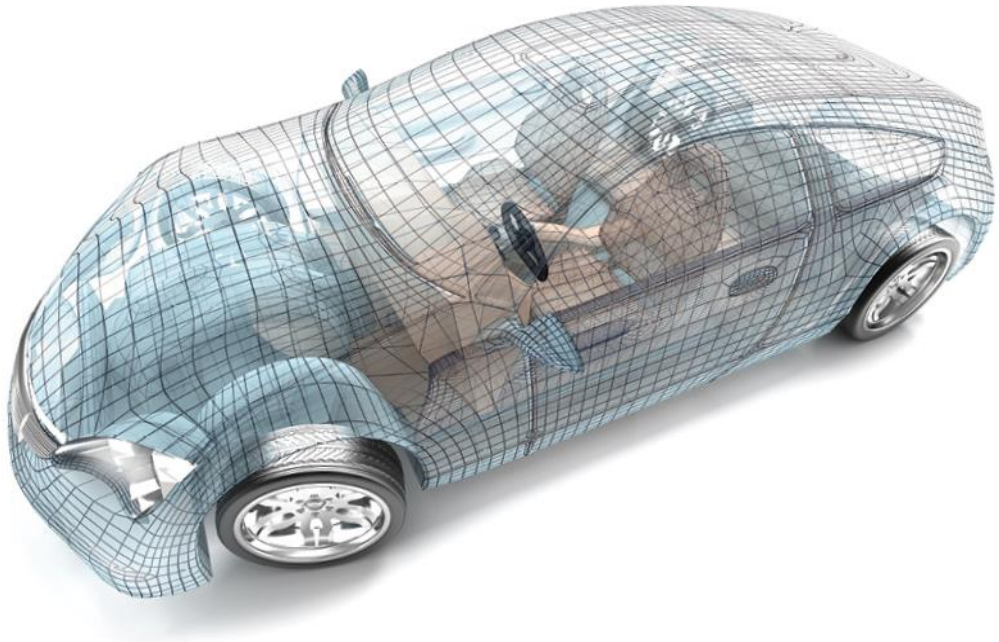
TCC 2020
THERMOPLASTIC COMPOSITES CONFERENCE

A VIRTUAL EVENT
APRIL 29 – MAY 1, 2020



Principles of joining of advanced thermoplastic composites

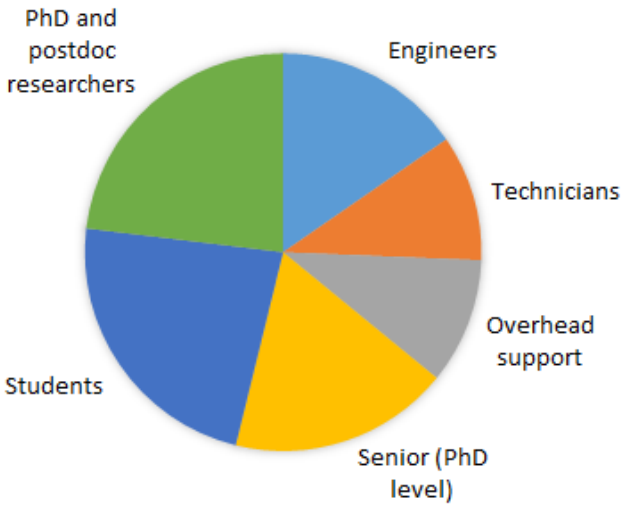
Presented By: Sebastiaan Wijskamp
Technical Director
ThermoPlastic composites Research Center - TPRC

ThermoPlastic composites Research Center – TPRC

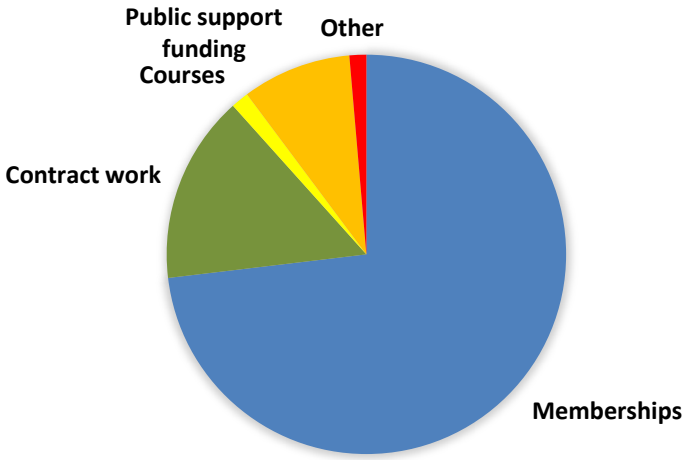
- Research consortium defines and steers roadmap research
- Fully equipped laboratory
- Training and workshops

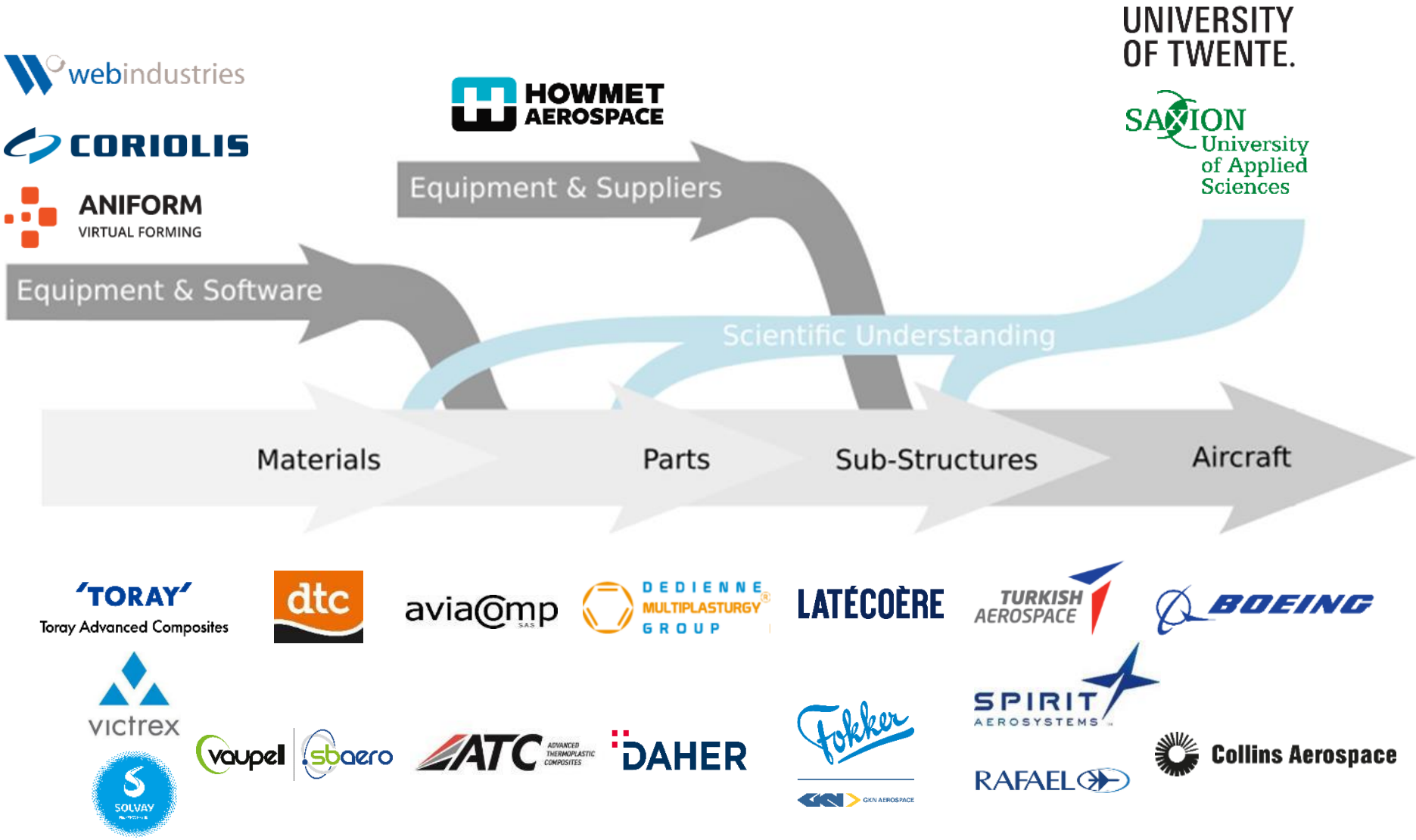
Staff	30
Graduates	10 - 15
Budget	2.5 M€
Members	22 (13 T1 & 9 T2)

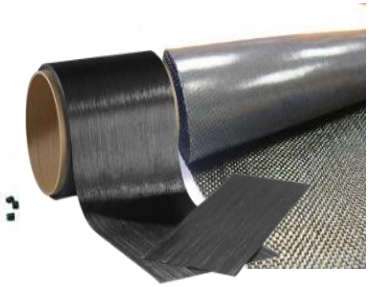
Headcount distribution

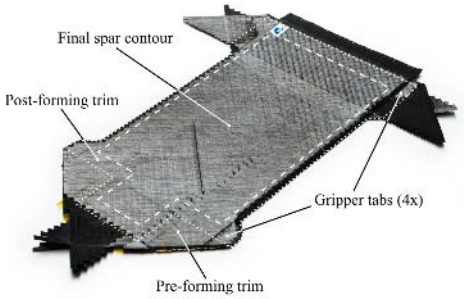


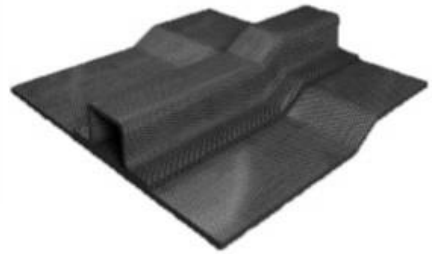
Revenue distribution



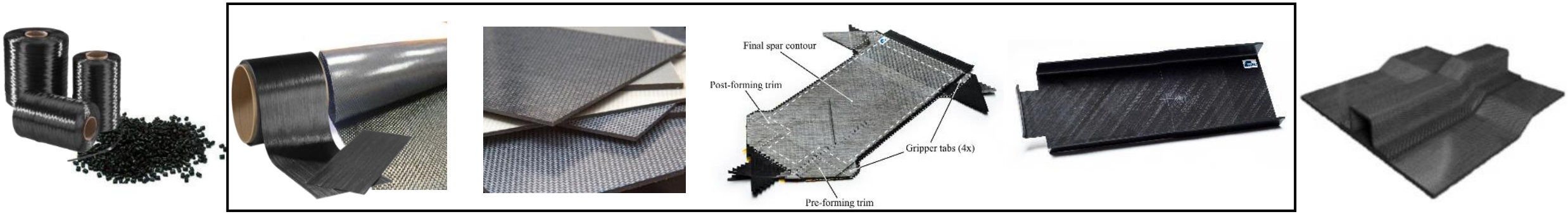

webindustries
CORIOLIS
ANIFORM
VIRTUAL FORMING
HOWMET AEROSPACE
UNIVERSITY OF TWENTE.
SAXION University of Applied Sciences
Equipment & Suppliers
Equipment & Software
Scientific Understanding
Materials
Parts
Sub-Structures
Aircraft
TORAY
Toray Advanced Composites
dtc
aviaMP
DEDIENNE MULTIPLASTURGY GROUP
LATÉCOÈRE
TURKISH AEROSPACE
BOEING
victrex
SOLVAY
vaupel
sbaero
ATC
DAHER
Fokker
GKN AEROSPACE
SPIRIT AEROSYSTEMS
RAFAEL
Collins Aerospace







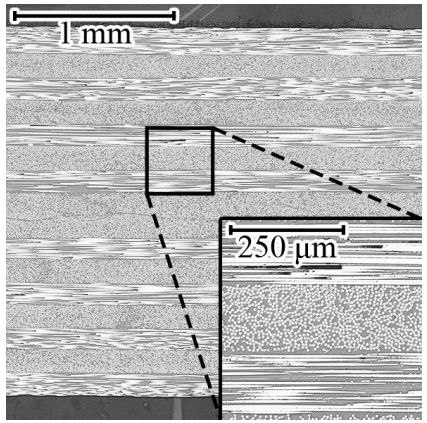
raw materials ➡ pre-preg ➡ laminate ➡ (tailored) blank ➡ component ➡ assembly

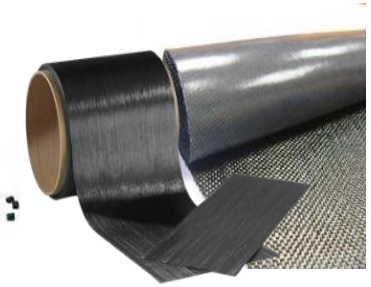


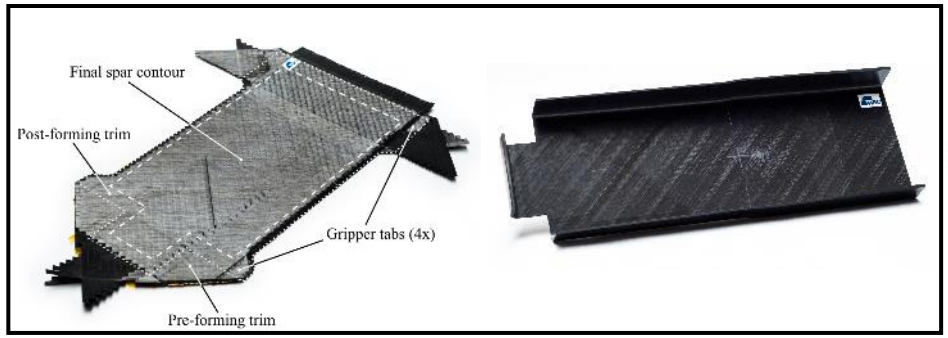
raw materials → pre-preg → laminate → (tailored) blank → component → assembly

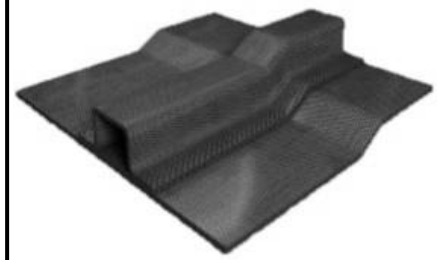
Consolidation

- Autoclave and vacuum-bag-only
- In-situ AFP
- AFP + out-of-autoclave



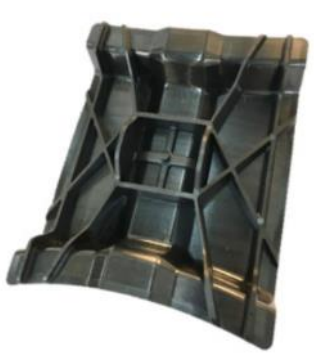


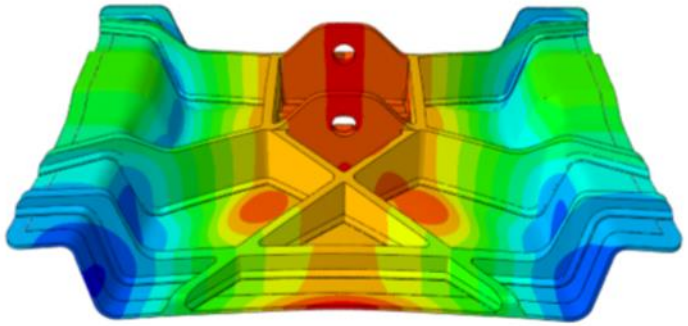


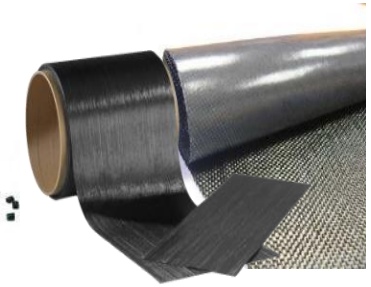
raw materials → pre-preg → laminate → (tailored) blank → component → assembly

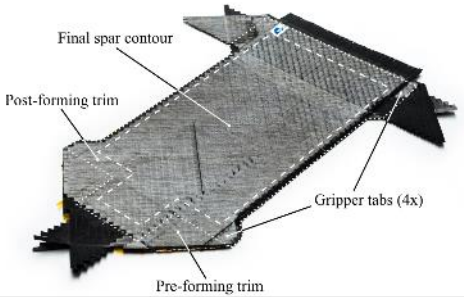
Advanced forming

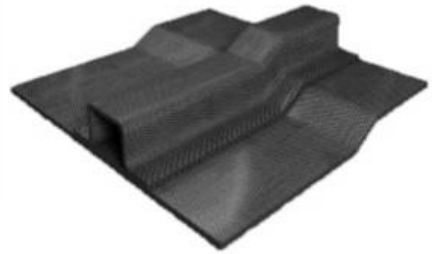
- Tailored blanks stamping
- Injection overmolding





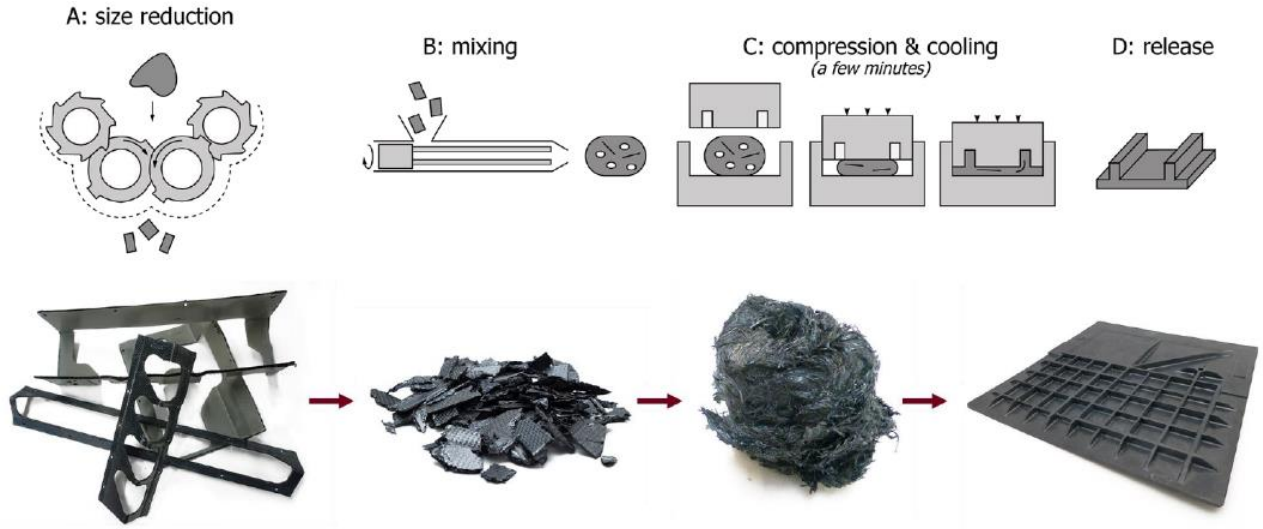


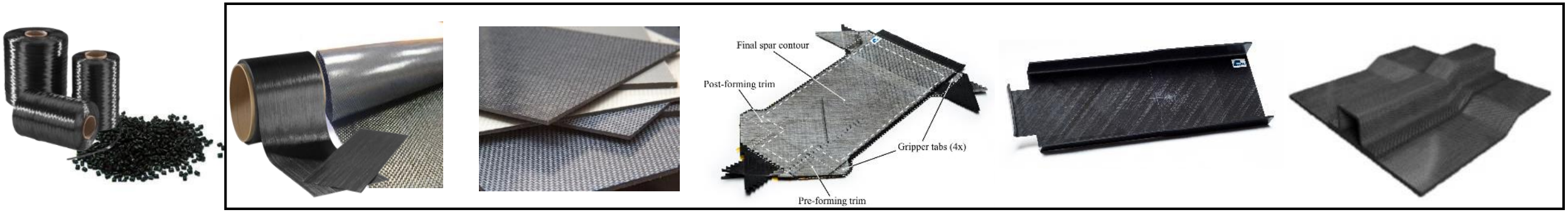



raw materials → pre-preg → laminate → (tailored) blank → component → assembly

Recycling

- Re-use of process reclaim
- Compression moulding

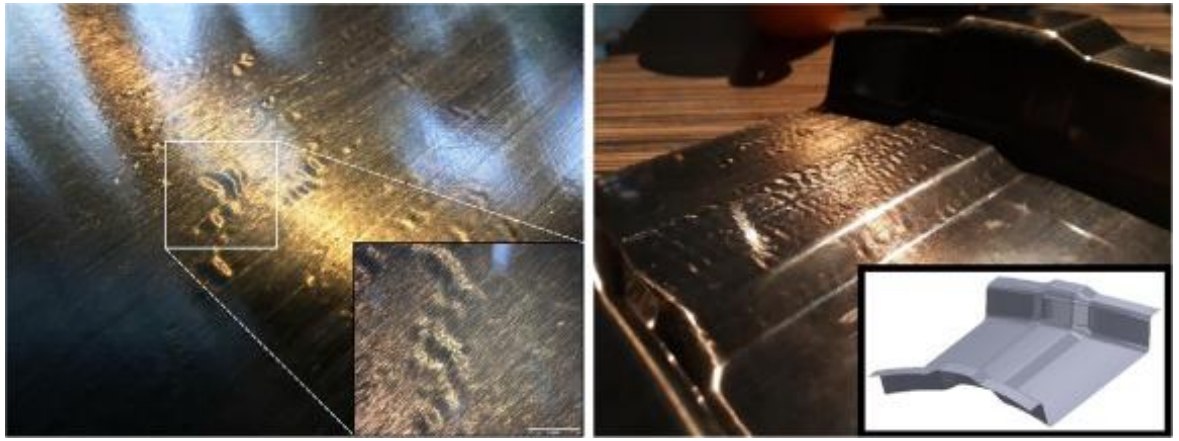


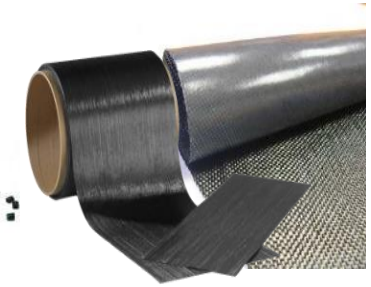


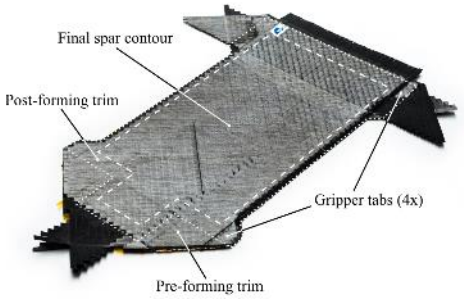
raw materials → pre-preg → laminate → (tailored) blank → component → assembly

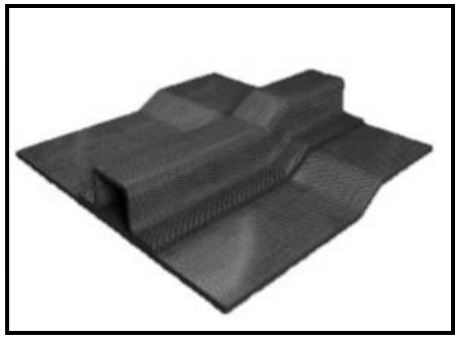
Process – performance interaction

- Thermal stability
- Creep & long term performance
- Defect free manufacturing





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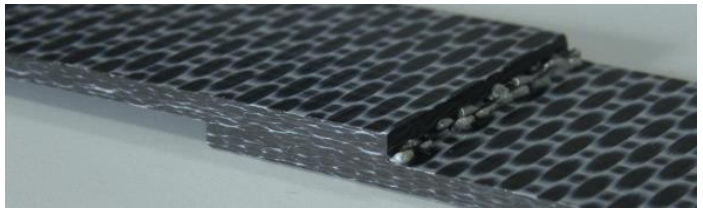
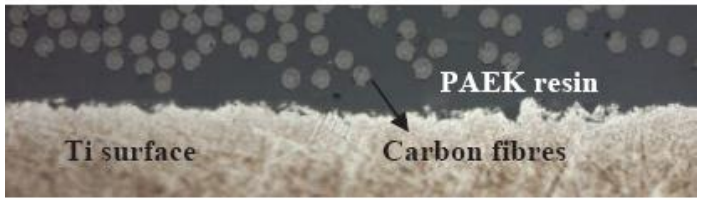
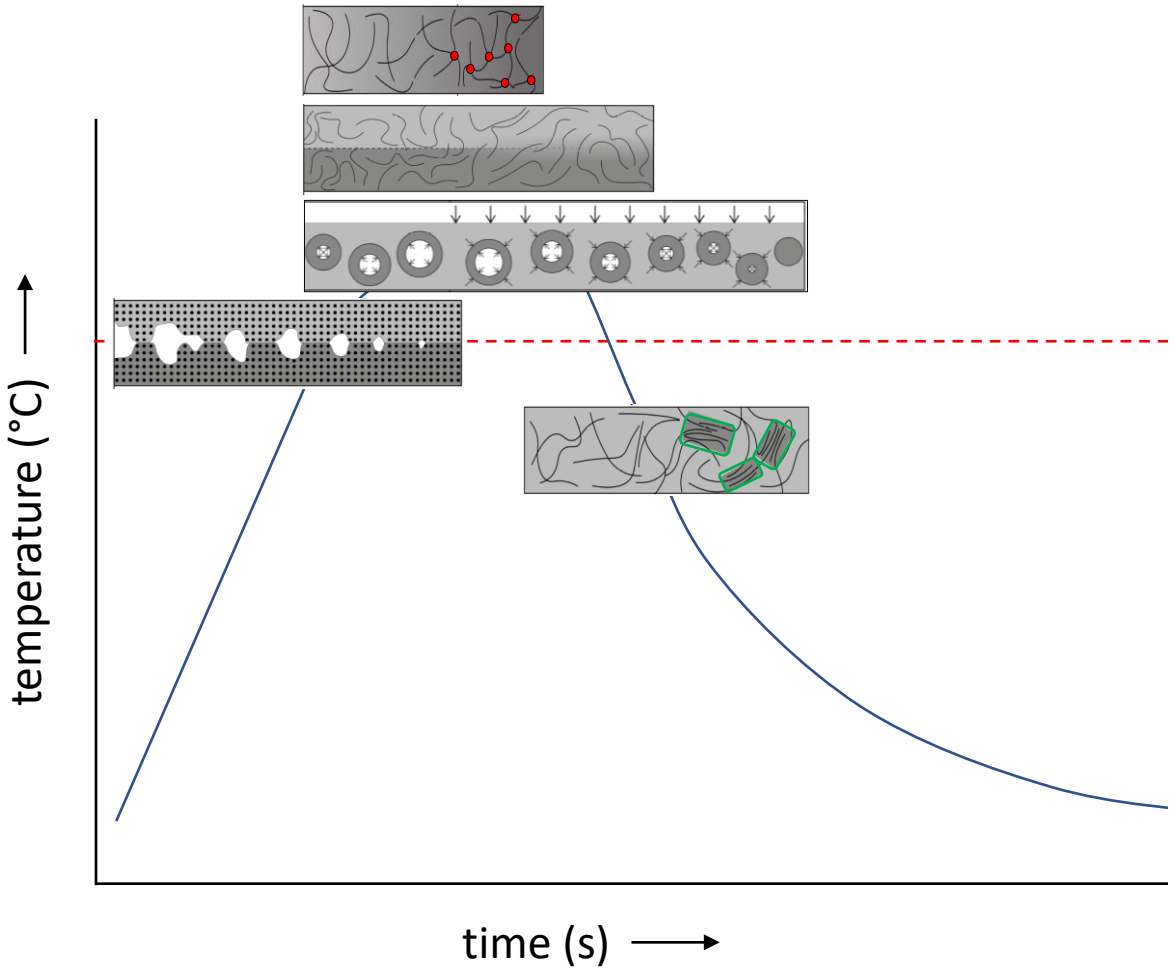
Joining

- Welding
- Hybrid joining
- Mechanical fastening

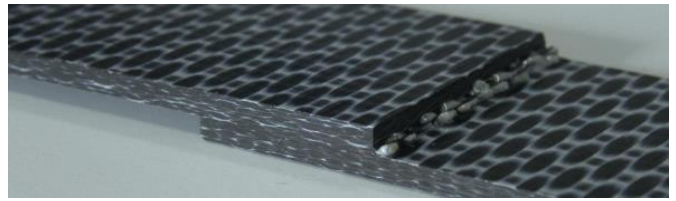
Approach to fusion bonding/welding

- Melt & cool as fast as possible
- Temperature and pressure drive
  - intimate contact development
  - healing
  - crystallization
  - de/reconsolidation
  - degradation
  - polymer squeeze out
  - residual stresses



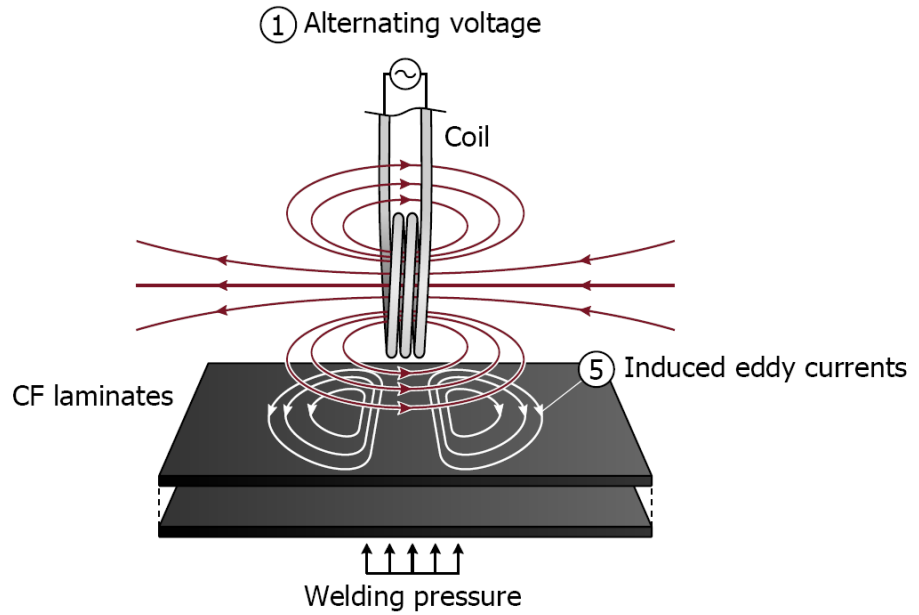
Induction heating shows high potential

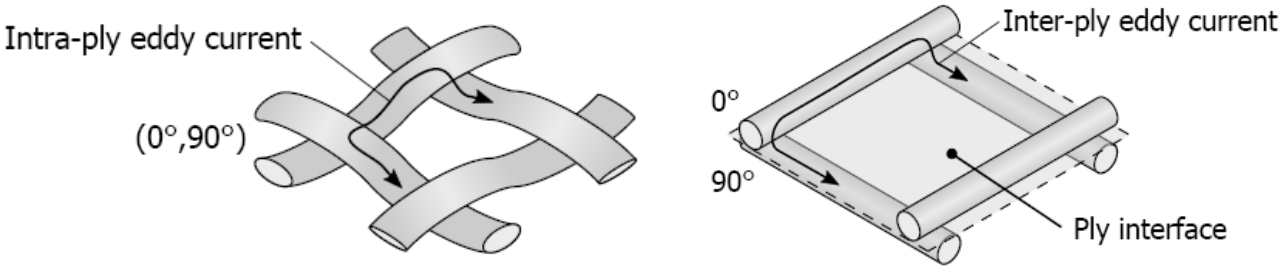
- Rapid welding without susceptor
- Works with carbon fibers
- Fabrics and UDs



Induction heating shows high potential

- Rapid welding without susceptor
- Works with carbon fibers
- Fabrics and UDs
- Current research focuses on fundamentals
  - test development for relevant electromagnetic properties
  - multiphysics process modelling





Outlook

- Further increase TRL of welding technology
- Advanced research into process – performance relation
  - micro, meso, macro scale
- Modelling combined with process monitoring and control
- Test development & standardization

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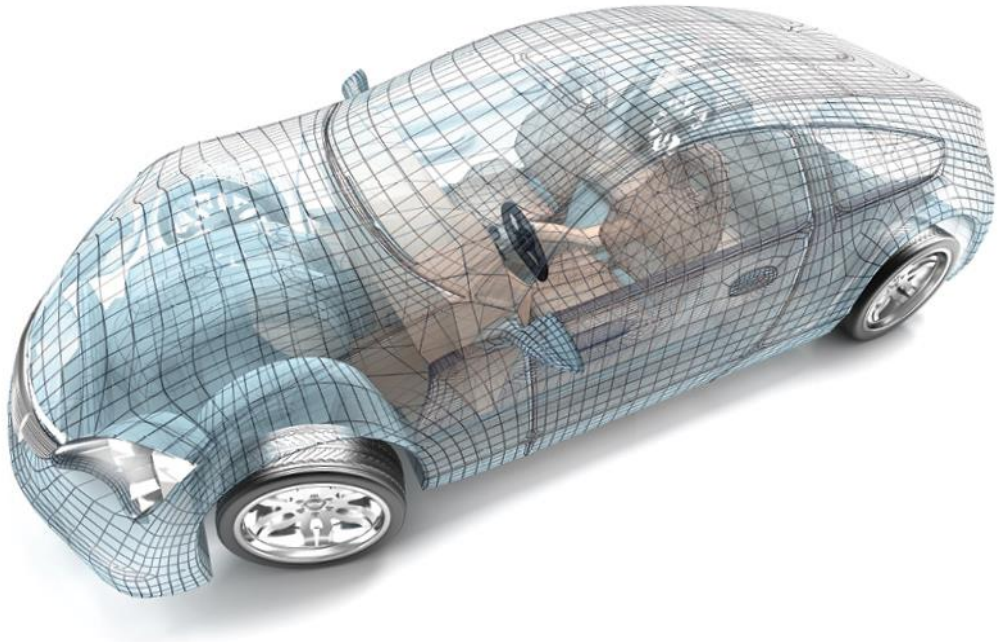


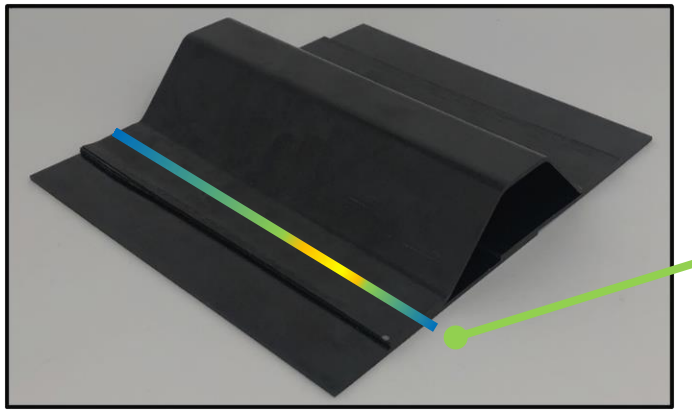
In-Situ Temperature Monitoring for Better Thermoplastic Welding

Presented By: Aida Rahim
Senior Applications Engineer
Luna Innovations

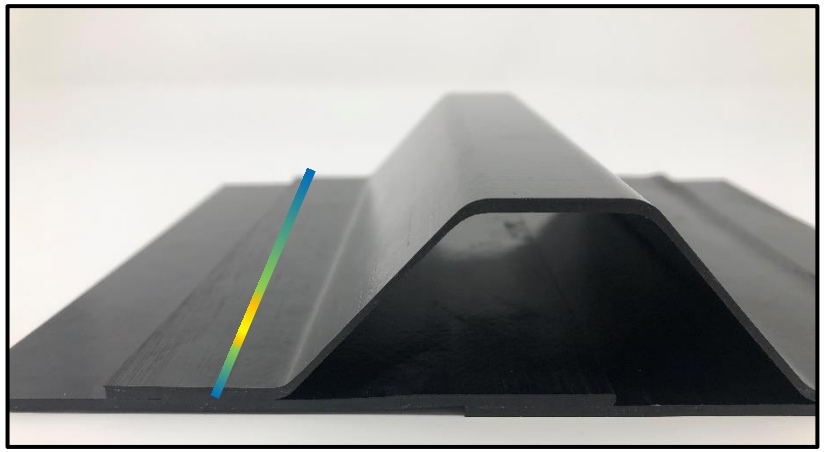
LUNA

UNIVERSITY OF SOUTH CAROLINA
McNAIR Center

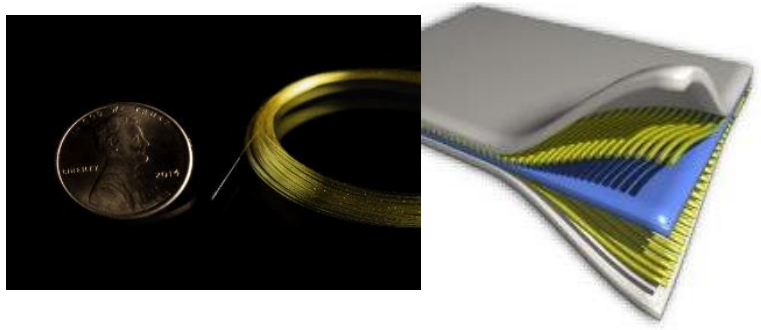
- Motivation:
  - Poorly formed bonds fail
  - Overheating causes internal stress and geometrical distortion
- Suggest a method using fiber optic sensors for monitoring thermoplastic welding processes
- Demonstrate a scheme for actively controlling the process
- Demonstrate performance and time improvements using non-linear control parameters



Embedded sensor shows thermal gradient within joint during welding

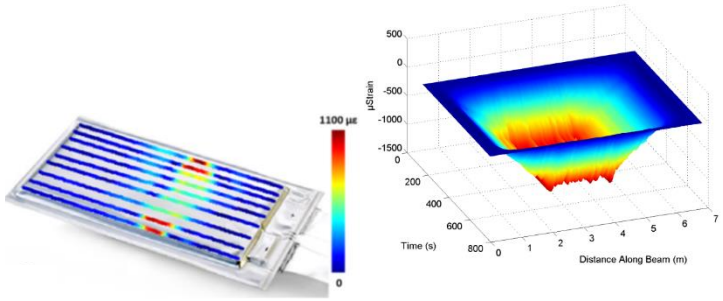


Can measure *where* you need data



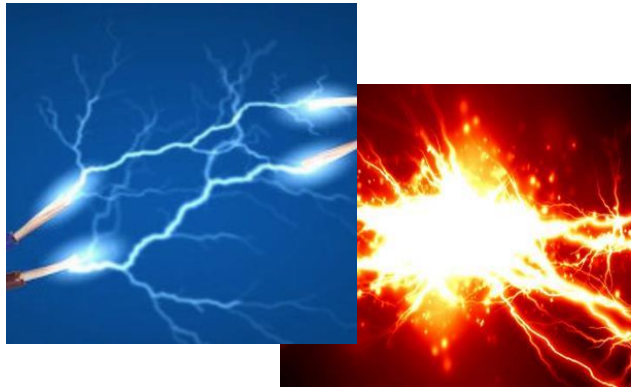
- Very small, low profile (easy to embed)
- Lightweight
- Flexible
- Distributed

Provides more data, more insight



- High-definition mapping of temperature
- Distributed sensing over large areas

Works in harshest environments



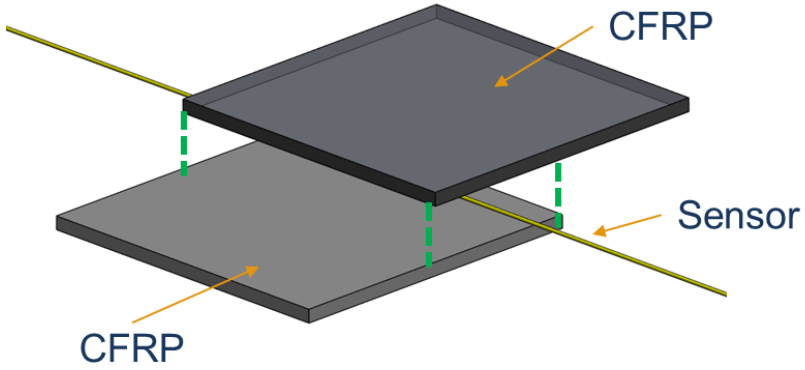
- Passive
- Immune to EMI
- Chemically inert
- Intrinsically safe

University of South Carolina McNAIR Center

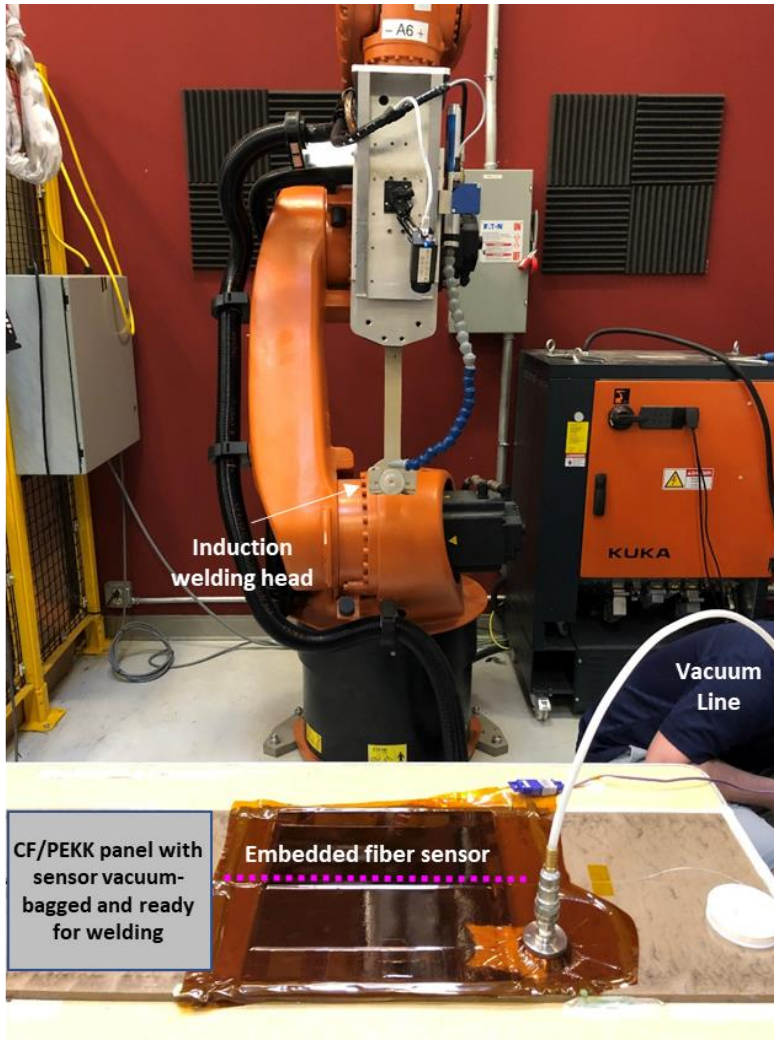
LUNA

Sensor placed between CF/PEKK Laminates

Lap-Shear configuration with 2.5cm overlap

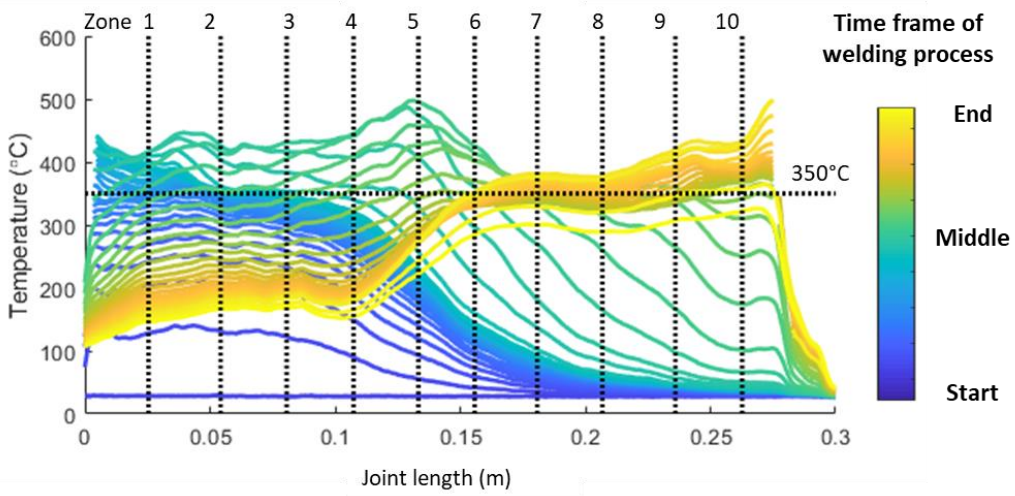


Active control of welding head rate based on spatial temperature profile

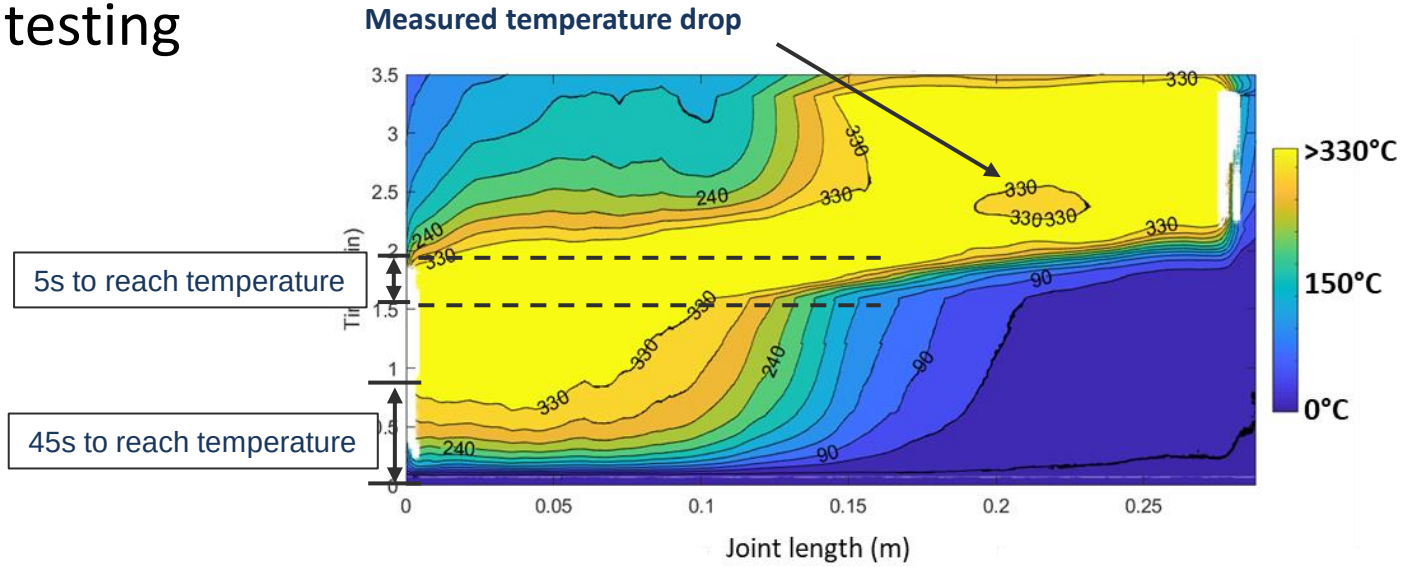


RESULTS: FEEDBACK CONTROLLED WELD

- Isotherms show it takes longer to reach temperature at the edges
- Centrally-located zones reach the set point faster due to the physics of heat generation in bulk material far away from edge effects
- Embedded sensor ensures appropriate time at temperature is achieved for bonding
- Entire process took 3.25 minutes which is approaching 50% faster than previous iterations using preset rates
- Joint did not fail during mechanical testing

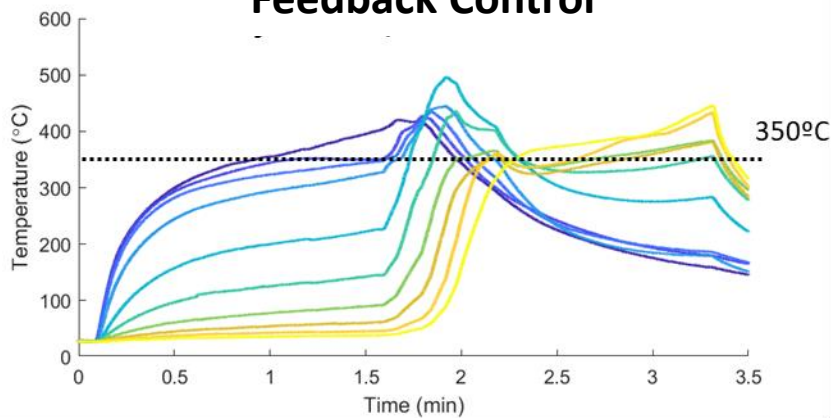


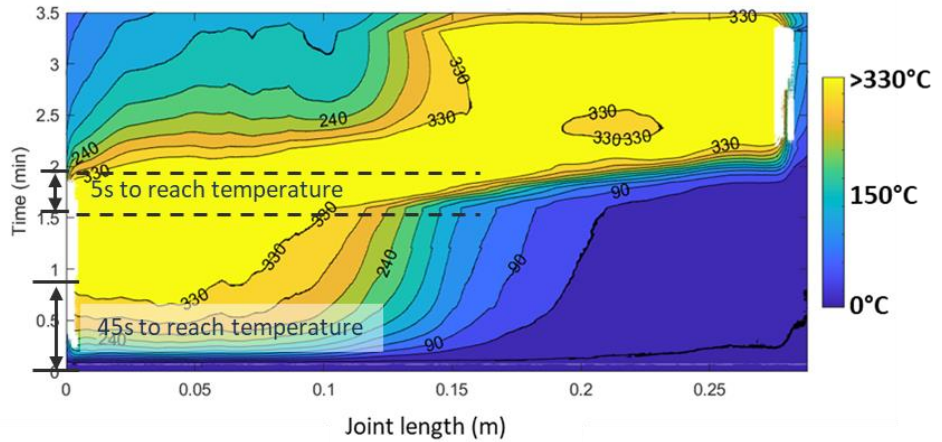
Temperature traces spaced 0.8 s apart



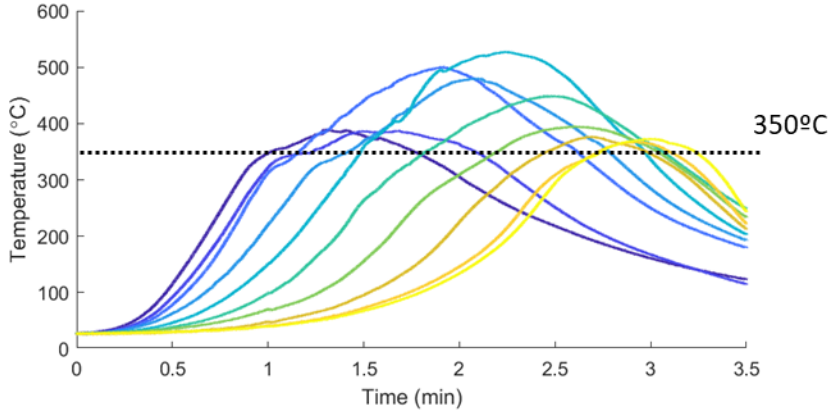
RESULTS: FEEDBACK CONTROL VS FIXED-RATE TRAVEL

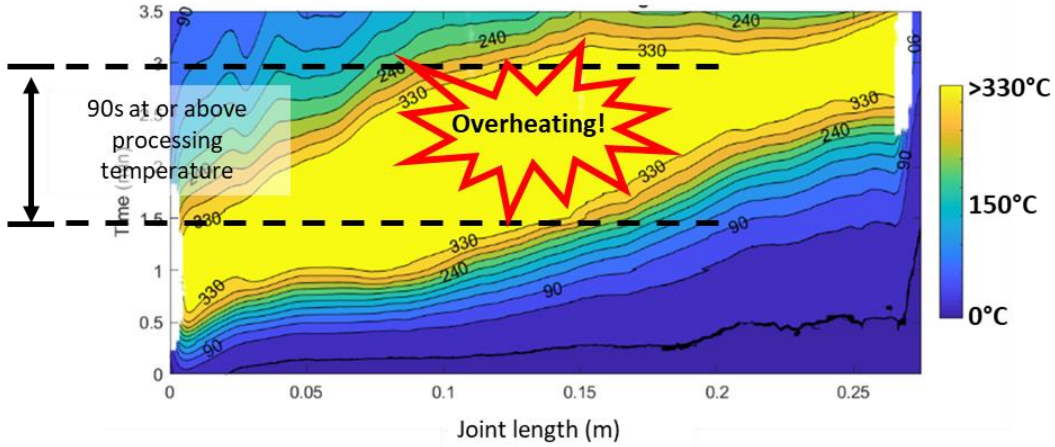
Feedback Control





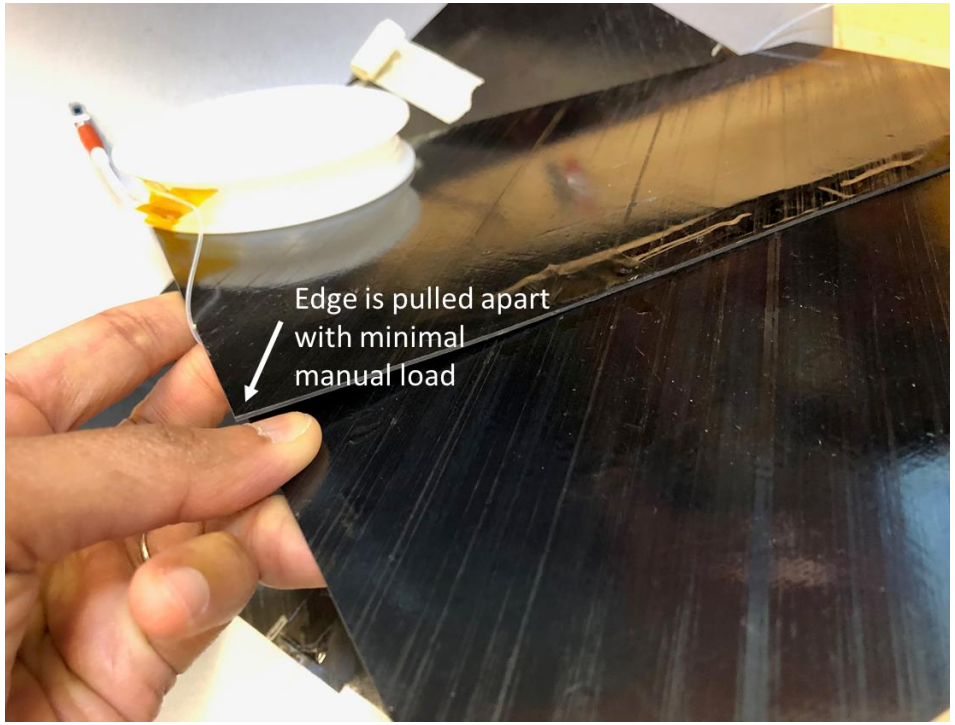
Fixed Rate Travel





Zone 1 2 3 4 5 6 7 8 9 10

Failed Fixed Rate Travel Weld



- Ends did not join
- Insufficient heat put into the edges
- Part failed during mechanical testing
- Controlled rate samples did not fail

- Sensor allows for non-linear control parameters to be determined
- Embedding a fiber sensor provides necessary data to control the process
- Actively controlling the process results in a better joint

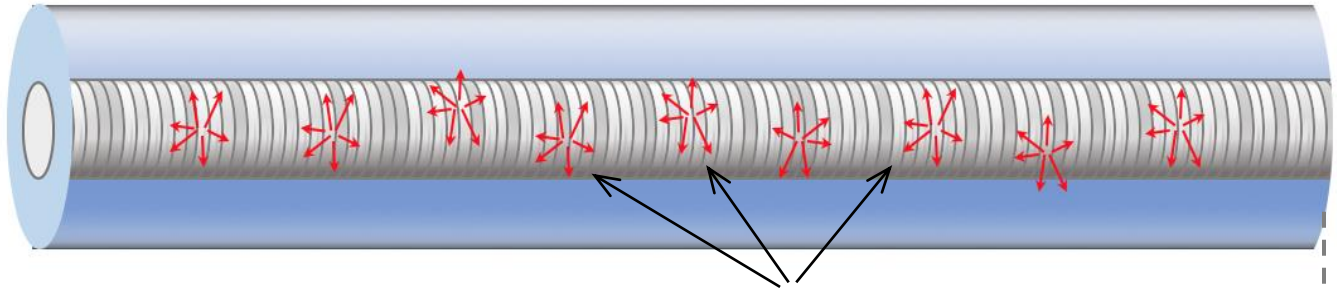
BACKUP

DISTRIBUTED SENSING: HOW IT WORKS

Tunable Laser Source

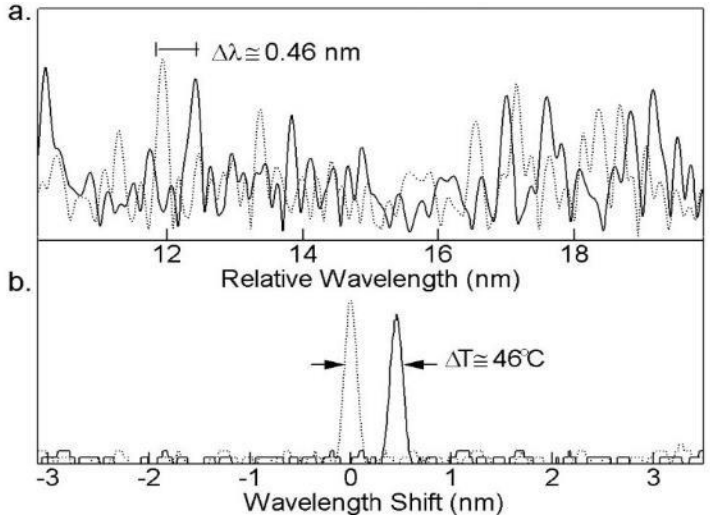
Rayleigh backscatter signal

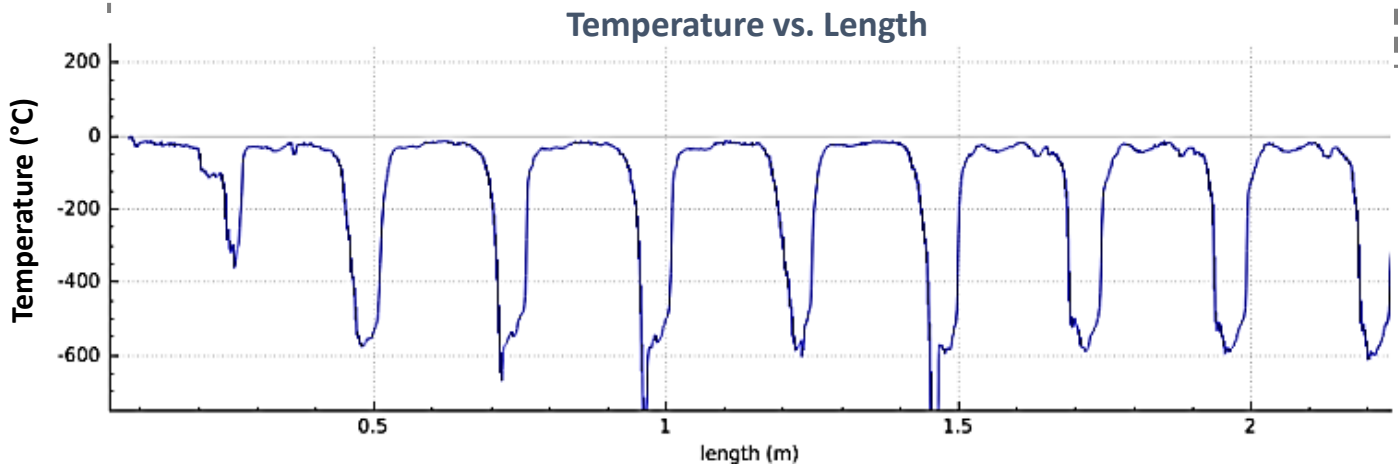
Optical Fiber



Rayleigh backscatter, due to natural minute variations in index of refraction in fiber core

- Backscatter provides unique “fingerprint” of optical fiber
- Frequency shift correlates to change in applied strain or temp.
- OFDR system resolves shift along fiber length





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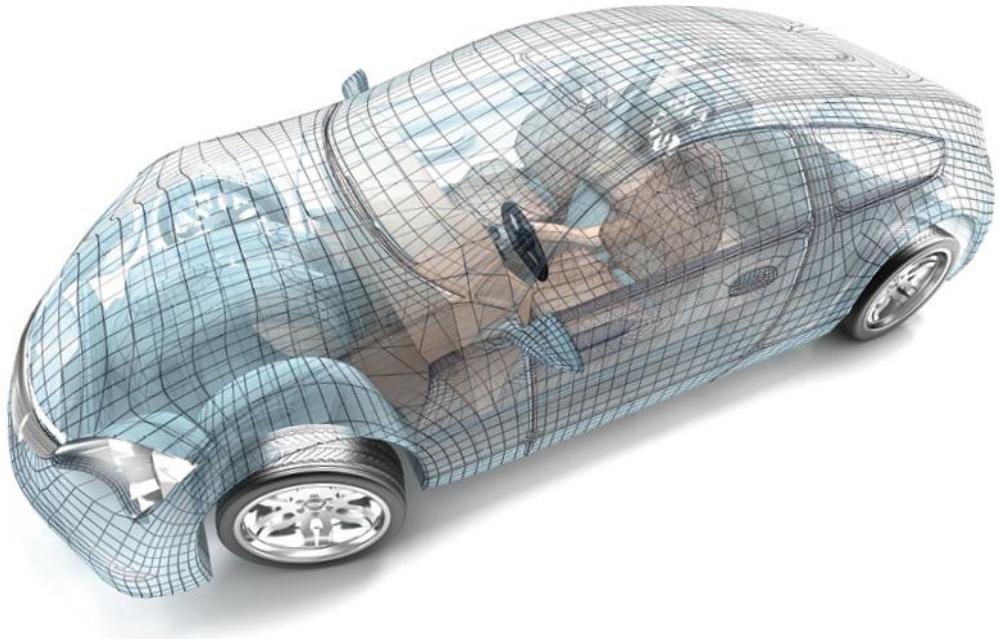
NIAR Wichita State University
National Institute for Aviation Research

ATLAS
Advanced Technologies Lab for Aerospace Systems

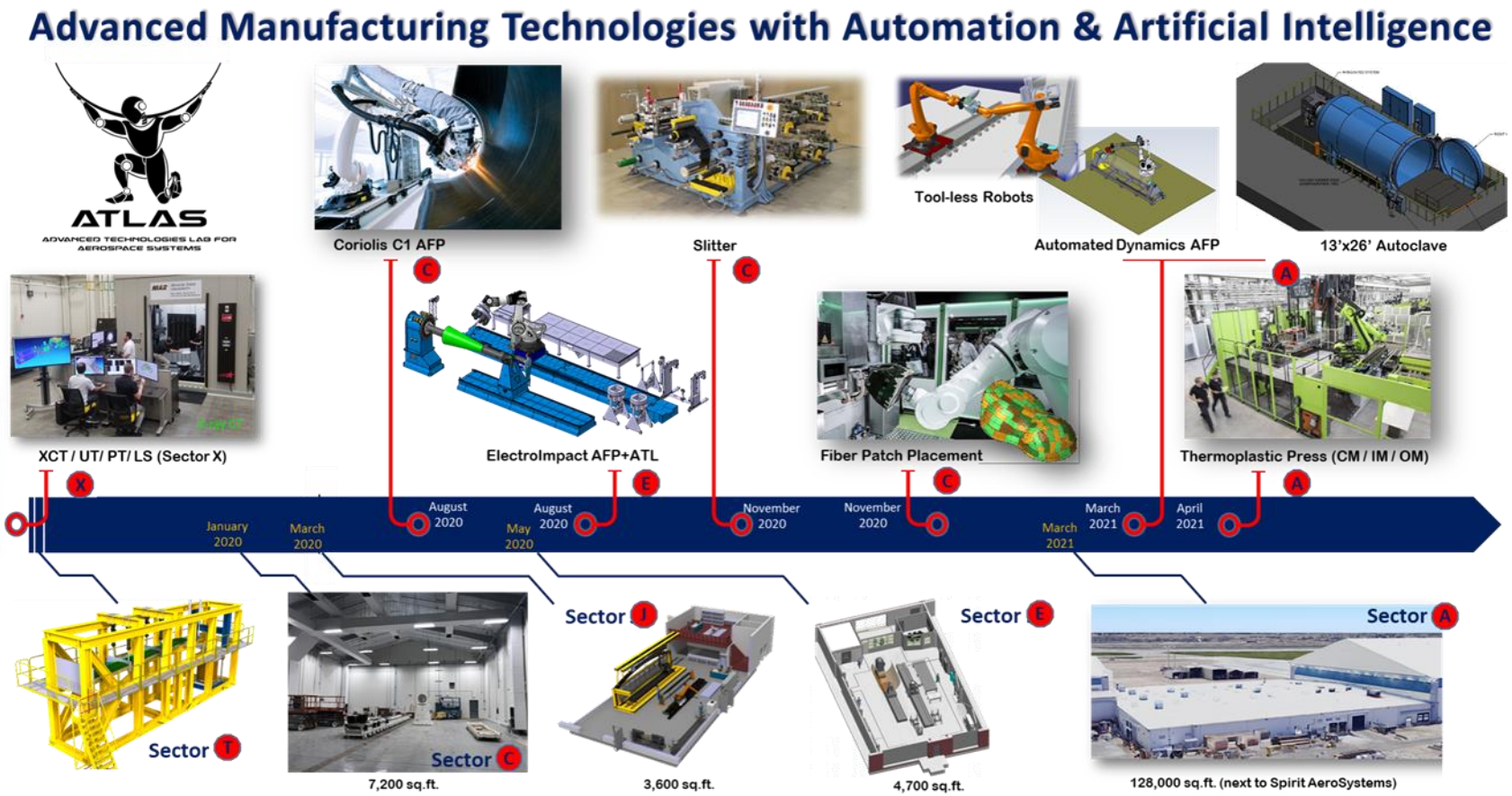


Factory of The Future: Advanced Manufacturing Technologies with Automation & Artificial Intelligence

Presented By: Waruna Seneviratne, PhD
Director ATLAS (Advanced Technology Laboratory for Aerospace Systems)
National Institute for Aviation Research (NIAR) / WSU

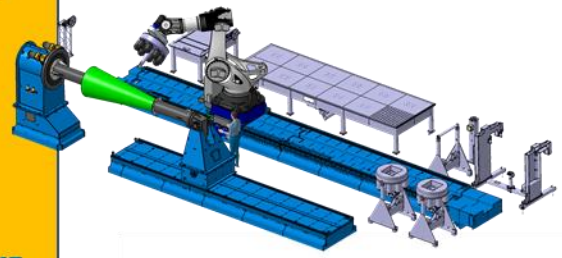
Develop a multi-disciplinary manufacturing environment and an engineering education program to prepare engineers and educators for the Factory of the Future and to aid the current workforce in seamlessly adapting to advancements in the workplace.

Advanced Manufacturing Technologies with Automation & Artificial Intelligence



Automated Manufacturing

- **Automated Fiber Placement** [Lead: Matt Tomblin]
  - Thermoset
  - Thermoplastic
  - Dry Fiber
- **Thermoplastic** [Lead: Brandon Saathoff]
  - Welding (Induction-Resistance-UT)
  - Compression Molding
  - Injection Molding
  - Over Molding



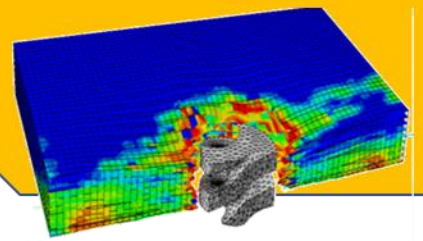
ATLAS

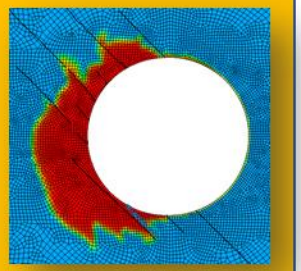
ADVANCED TECHNOLOGIES LAB FOR AEROSPACE SYSTEMS

Computer-Aided Simulations & Analysis

[Lead: Mohamad Shafie]

- Manufacturing Simulations
- Process Modeling
- Stress Analysis





High-Fidelity Inspections

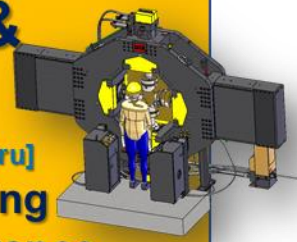
[Lead: Caleb Saathoff]

- X-Ray CT (XCT)
- MAUS (UT)
- Acoustic Emission (AE)
- Pulse Thermography (PT)
- Laser Shearography (LS)
- Digital Image Correlation (DIC)

Structural Test & Evaluations

[Lead: Caleb Saathoff & Upul Palliyaguru]

- Biaxial Axial-Torsion Testing
- Durability & Damage Tolerance
- Structural Health Monitoring
- Aging Evaluations and Life Extension
- Repair Evaluations

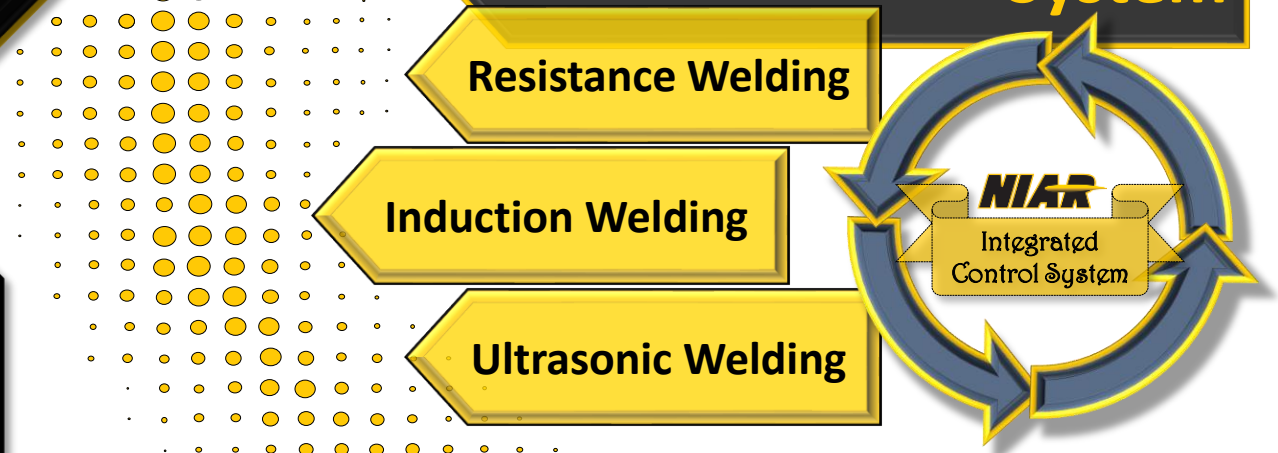


Benefits of Thermoplastic Composite Welding

- Minimizes the use of mechanical fasteners
- No extensive surface preparation required unlike adhesive bonding (low surface free energy **requires** surface treatment)
- Can significantly reduce assembly time & overall cost
- Unleashes ability to integrate large structures
  - In some cases, no added materials are necessary at the weld interface

- Develop a multifunctional thermoplastic welding system capable of interfacing with resistance, induction, and ultrasonic welding technologies to aid in controlling and monitoring the welding process to generate repeatable quality welds
  - 1 platform will control and monitor each individual welding process (closed loop) for all 3 welding techniques included
- Simulation tools will be developed and validated experimentally
  - Coupons will initially be used to highly control boundary conditions on lab-scale equipment
  - Through process simulation, techniques will be evaluated for their ability to scale to large structure applications and large continuous welds will be performed to validate analytical predictions

Multifunctional Thermoplastic Welding System

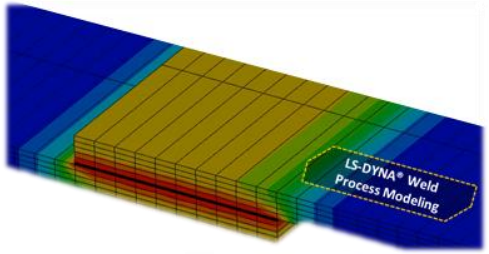


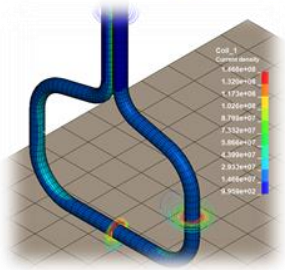
- Process Variability Control
- Optimized Manufacturing Strategies
- Tool Development
- Scaling

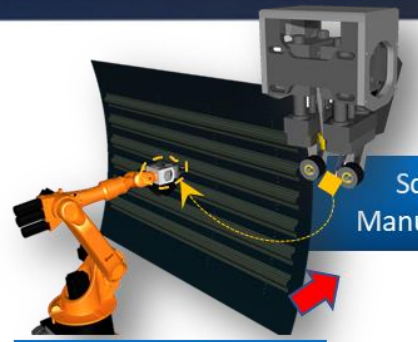
Modeling for Affordable Sustainable Composite (MASC)

AFRL

NIAR Wichita State University National Institute for Aviation Research



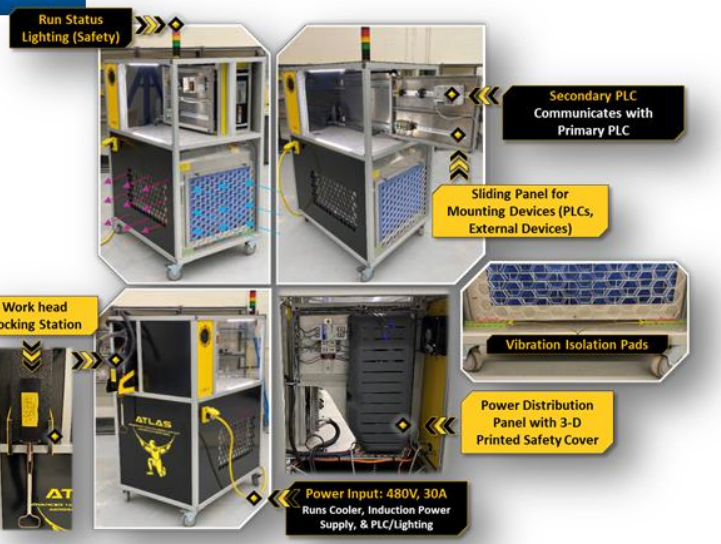




Scale Up Manufacturing

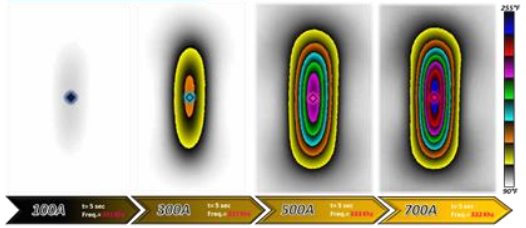
Close-Loop Controls

Integrated Systems

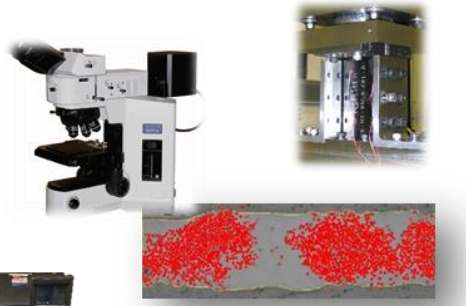


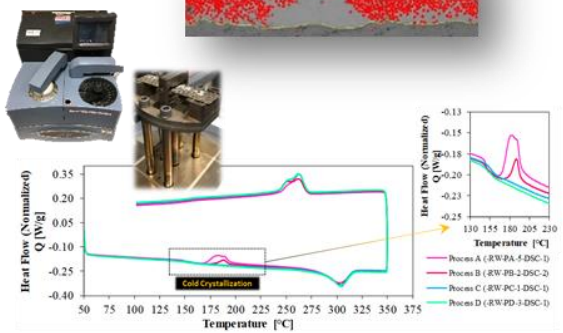
Simulations

High-Fidelity Inspections



Control Benchtop Experiments





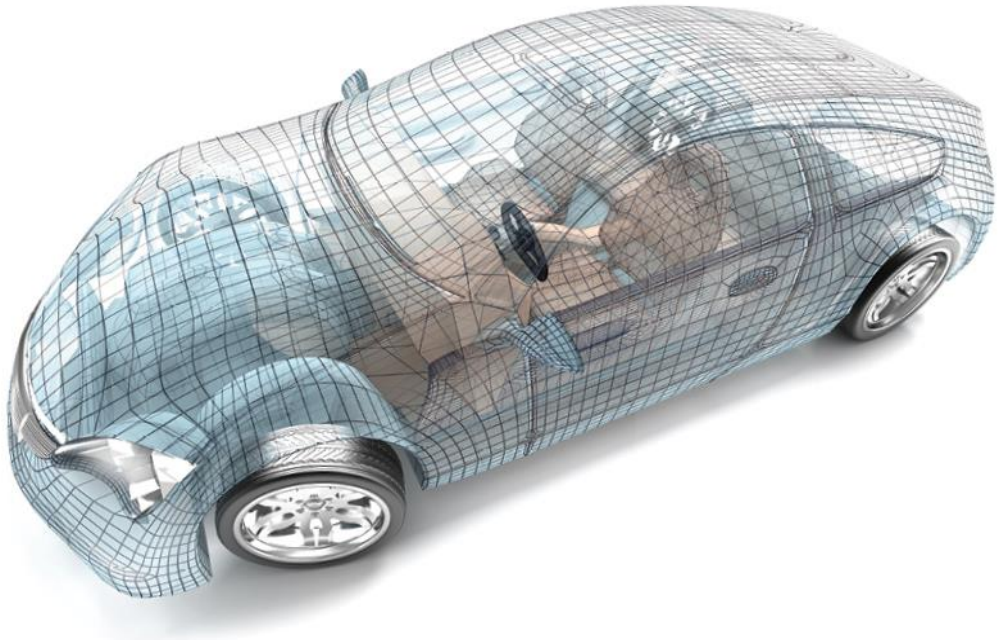
Material Characterization

NCAMP

CMH-17 Composite Materials Handbook

TCC 2020
THERMOPLASTIC COMPOSITES CONFERENCE

A VIRTUAL EVENT
APRIL 29 – MAY 1, 2020



ACMA Bonding and Joining Panel- FAA Thermoplastics Certification and Research

Presented By: Danielle Stephens
Aerospace Engineer
Structures & Materials Section; Aviation Research Division
William J. Hughes Technical Center
Federal Aviation Administration

FAA INTEREST IN THERMOPLASTIC COMPOSITES

- The FAA's goal is safe implementation of thermoplastic composites into aviation products
- We have established protocols for traditional continuous fiber thermoset materials that may apply
  - Research will be used to see if we need to amend any existing guidelines because of the change to thermoplastic
  - Areas of concern include M&P control, Bonding and Welding, Strength Substantiation, F&DT, Flammability, Crashworthiness, Lightning Protection, and Repair/Maintenance
  - FAA will also investigate what affect different thermoplastic manufacturing methods have on any of the concerns identified above

- Thermoplastic bonding and welding
  - Define the two processes (what makes them different) and then really look into our existing guidance to see if it is still valid
  - Review the kinds of applications that are being proposed for both bonding and welding of thermoplastics

CERTIFICATION GUIDANCE

- The FAA publishes many documents that provide guidance on design approvals; one comprehensive "how to guide" is *The FAA and Industry Guide to Product Certification*

Composites are Non-Standardized

–Thermoplastics, CMCs, and DFC even less so than thermoset continuous fiber PMC

–Early successful applications are linked to conservative design principles and integrated product development, often with a point design certification approach

–Mature applications still require semi-empirical solutions, most commonly based on the building block approach

– Best to <u>engage the FAA early and often for effective knowledge transfer of new technologies</u>

http://www.faa.gov/aircraft/air_cert/design_approvals/media/CPI_guide_II.pdf

GUIDANCE IS LACKING

- **AC 20-107B is the FAA's most comprehensive guidance for certification of composite structures**
  - Harmonized with EASA AMC 20-29
  - Relatively high-level
  - Attempts to address regulatory requirements utilizing a safety management philosophy
- **Bond guidance not yet rigorously applied to thermoplastics – it applies… until found unacceptable**
- **Working with industry to create bond vs weld definitions**
- **Treat each scenario project by project**

How do we fix this?
Work with industry! - Research and Evaluation

AMC 20-29 Effective: 26/07/2010
Annex II to ED Decision 2010/003/R of 19/07/2010

AMC 20-29
Composite Aircraft Structure

Advanced Fiber Reinforced Polymer Materials Guidelines for Aircraft Design Certification Process

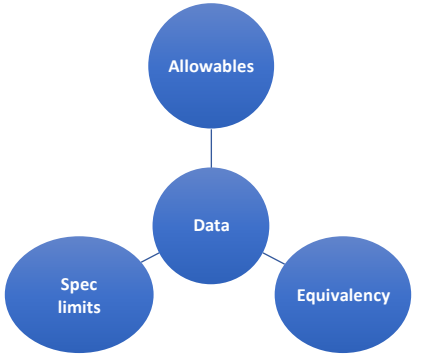
Overall Goals

- Develop a framework for the qualification of new and innovative composite material systems including guidelines and recommendations for their characterization, testing, design and utilization.
- Develop a material property shared database and transition to publicly available source (CMH-17).

TASK 1: Survey & Establish Steering Commit → **TASK 2:** Develop Qualification Framework → **TASK 3:** Validate framework with selected materials → **TASK 4:** Establish statistical guideline s → Transition
- Material property data
- Guidelines

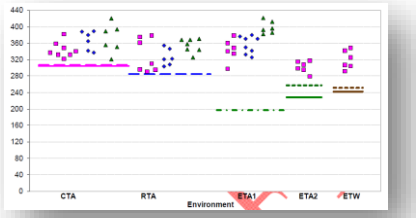
Qualification Program material chosen based on industry input:
Continuous Fiber Thermoplastic

- Toray - TC1225 unidirectional tape
- Thermoplastic semi-crystalline engineered polyarlyetherketone resin



Status:

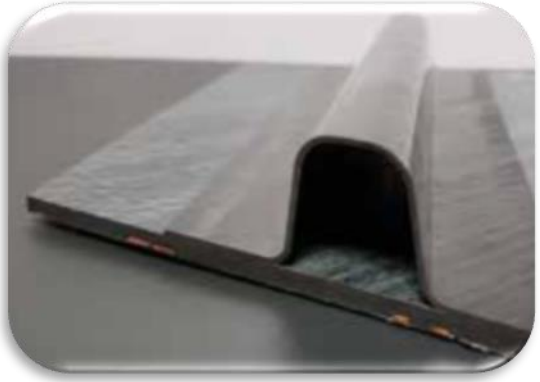
- Screening trials and full qualification now complete
- All documents have been reviewed by Industry Steering Committee and have just been released Feb 2020
- Equivalency on a continuous compression molding process is underway



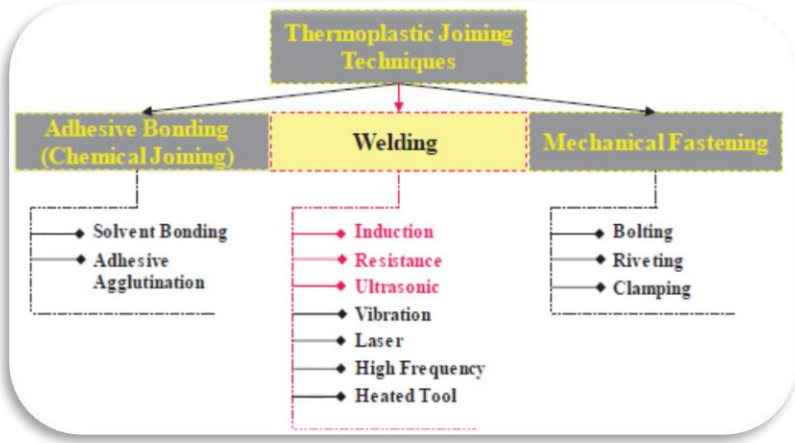
Statistical Allowables Generated

NIAR Wichita State University National Institute for Aviation Research

Thermoplastic Welding Process Qualification Protocols for Aircraft Design and Certification



High-performance thermoplastic resin systems with reinforcement are attractive to aircraft structural applications.
→ Several challenges have limited their widespread adoption- especially the lack of established best practices for adhesive bonding and welding



- **The primary goal of this research program is to develop a framework for the qualification of thermoplastic joints:**

Task 1: Literature Survey and Establishing Steering Committee
Task 2: Effects of Surface Preparation on Thermoplastic Bonded Joints
Task 3: Effects of Process Parameters on Thermoplastic Welded Joints
Task 4: Qualification Framework Development

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FEDERAL AVIATION ADMINISTRATION

Summary of Tasks

- **Task 1: Literature Survey and Establishing Steering Committee**
- **Task 2: Effects of Surface Preparation on Thermoplastic Joints**
  - Effects of surface preparation techniques on secondary bonded joints will be evaluated in order to develop bond process qualification protocols
  - Applicability of standard bonded joint evaluation test protocols will be examined.
- **Task 3: Effects of Process Parameters on Thermoplastic Welded Joints**
  - Assessment of critical parameters in the welding process to develop guidelines and recommendations for structural welding
  - In contrast to secondary bonding, minimal surface preparation is necessary prior to the fusion bonding process. However, effects of surface preparation techniques on fusion welded joints will be evaluated to investigate potential improvements to welded joints' strength and durability.
- **Task 4: Qualification Framework Development**
  - A framework for qualification will be created in collaboration with industry experts.
  - In addition to qualification guidelines, similarities and differences between the two joining processes and the impact on certification guidelines will be explored.

Summary

- Thermoplastic composite guidance is lacking
- Certification handled on a project by project basis – Engage FAA early
- Encourage industry participation in Steering Committees and research projects

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