

Intelligent process monitoring and control to take composites processing to the Industry 4.0 era

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Background

- **Closed Composites Moulding is a 'blind' and complex process**

Furthermore

- **Process monitoring in composites production is very 'primitive' even in aerospace**
 - **No real feedback from the cavity until demoulding**
 - **Only Temperature is being monitored (and in most cases far from the part)**

This eliminates the possibility to track and solve problems during production but also the possibility to solve the problems later (since no relevant data exist)



The Resin monitoring system

- **Check resin quality and adjust process accordingly**
- **Detect accurately resin arrival at critical locations**
 - **Open/close valves based on sensors' feedback**
- **Monitor viscosity changes and decide when start heating**
- **Identify minimum viscosity and decide about pressure**
- **Detect unexpected events and follow alternative routes**
- **Improve simulation accuracy and design intelligent strategies**
- **Real-time decision of the cure cycle based on T_g and degree of cure (depends on the resin) rather than time**



ECOMISE Project

Enabling Next Generation COMposite Manufacturing by In-Situ Structural Evaluation and Process Adjustment

Objective

A breakthrough composite manufacturing system is being developed comprising probabilistic process prediction, online process monitoring, in-situ structural evaluation and in-situ process adjustment. By means of industrial applications the focus is laid upon preforming processes such as pick & place and dry fibre placement, as well as subsequent infusion and curing processes such as Resin Transfer Infusion (RTI) and Resin Transfer Moulding (RTM).

Industrial Demonstrators

- Aerospace (Bombardier)
- Automotive (Hutchinson)
- Marine (Airborne)



Airborne

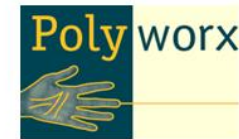
BOMBARDIER
the evolution of mobility

DASSAULT
SYSTEMES



HUTCHINSON®

SIEMENS

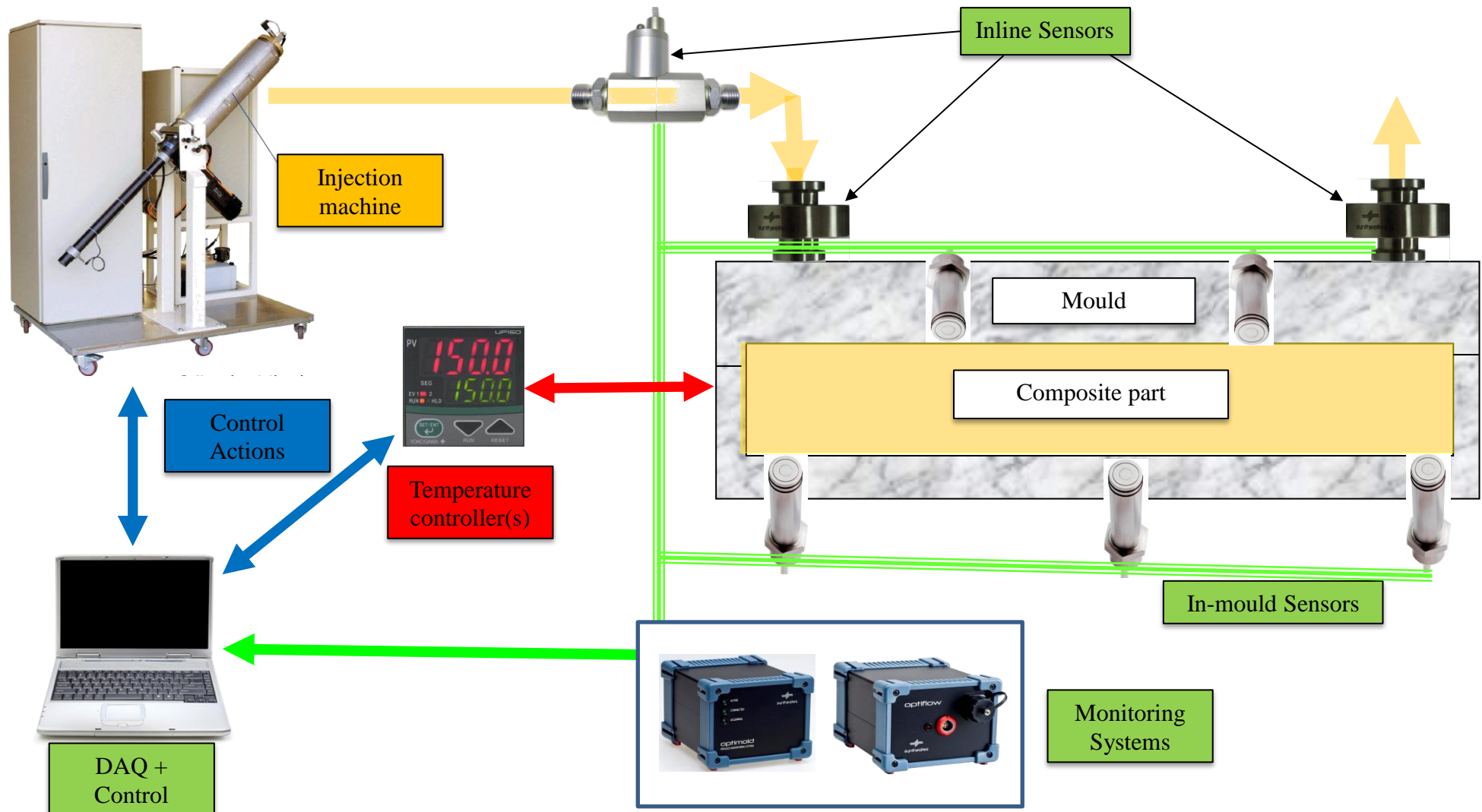


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www.ecomise.eu



Intelligent Closed Moulding



Optimold: Cure, viscosity, resin quality check

Real-time measuring of

- Resin's electrical resistance (from 0.1 MOhm up to 50 TOhm)
- temperature (pt100 sensor with 0.1°C accuracy)

Input of external signals e.g. pressure sensors

process monitoring sensor = electrical resistance + RTD sensors

New



Durable
sensor



High Temp RTM

- Resin arrival
- Viscosity rise
- Gelation
- End-of-cure

Flexible
sensor



VI and RT cure

- Resin arrival
- Viscosity rise
- Gelation
- End-of-cure

Inline sensor



- Avoid pipe cleaning
- Adjust cycle
- Mixing ratio check

Pot sensor



- Mixing ratio
- Resin Quality
- Resin aging
- Adjust cycle

New

Curved
Durable



OptiFlow: Resin arrival, temperature

- 4 temperature and resin arrival sensors
- Resistance-based measurements and RTD temperature
- Continuous connection checking
- One relay output for process automation



In-mould
Durable



- flat areas
- possible mark

New Gate
sensor



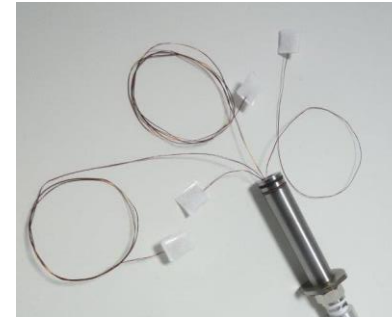
- ideal for vacuum infusion in oven/ autoclave (gates, pipelines, pots etc.)

Flexible
disposable



- Curved surfaces
- In the laminate for development
- Over the peel-ply
- Suitable for very long parts
- no extra protection for Carbon Fibre Preforms

New FloWire
sensors

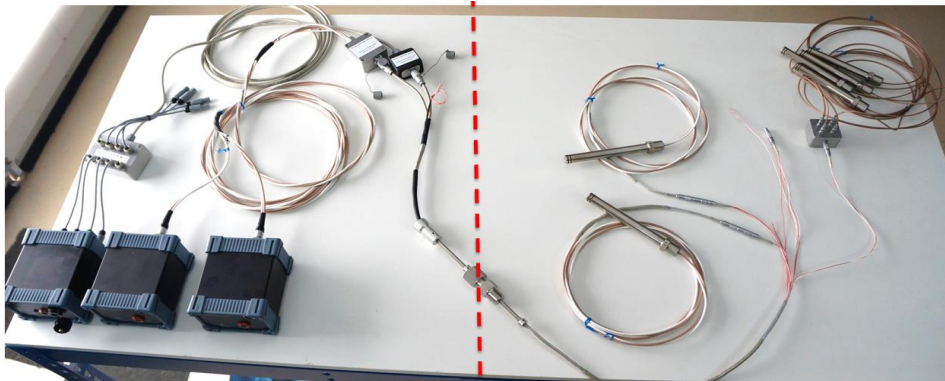


New Curved
Durable



Monitoring configurations developed within ECOMISE

- For autoclave, RTM and oven

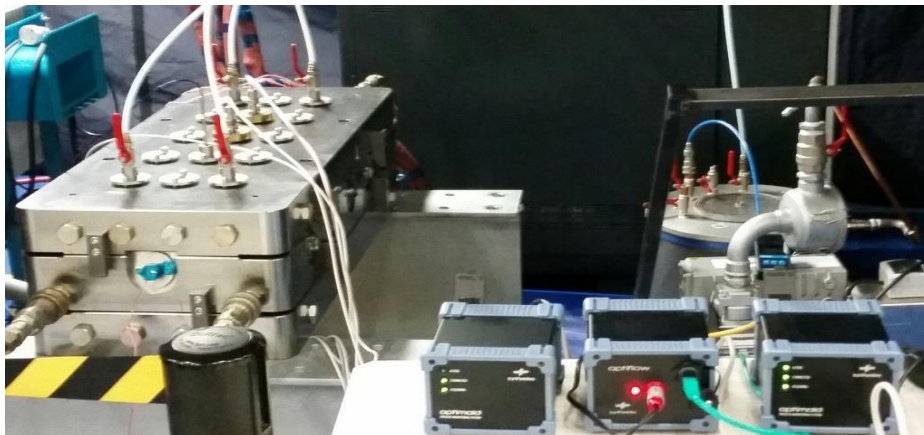


Outside of the autoclave

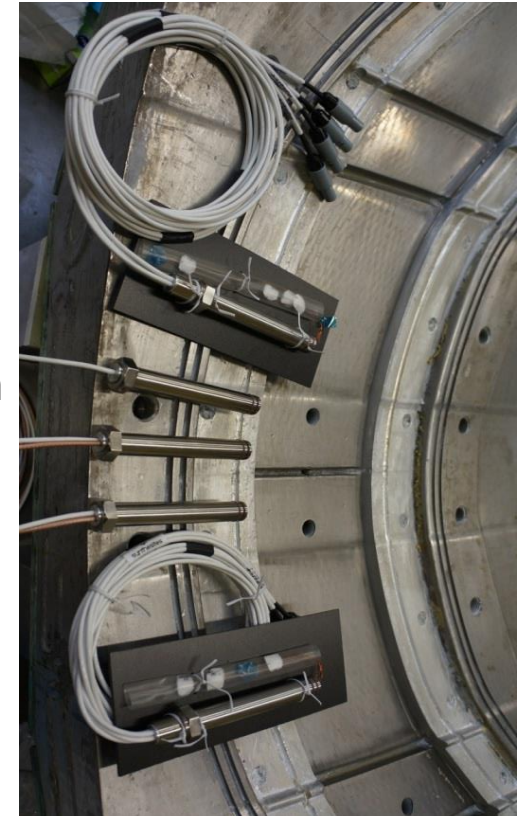
Inside of the autoclave

Bombardier
Aerospace
Belfast

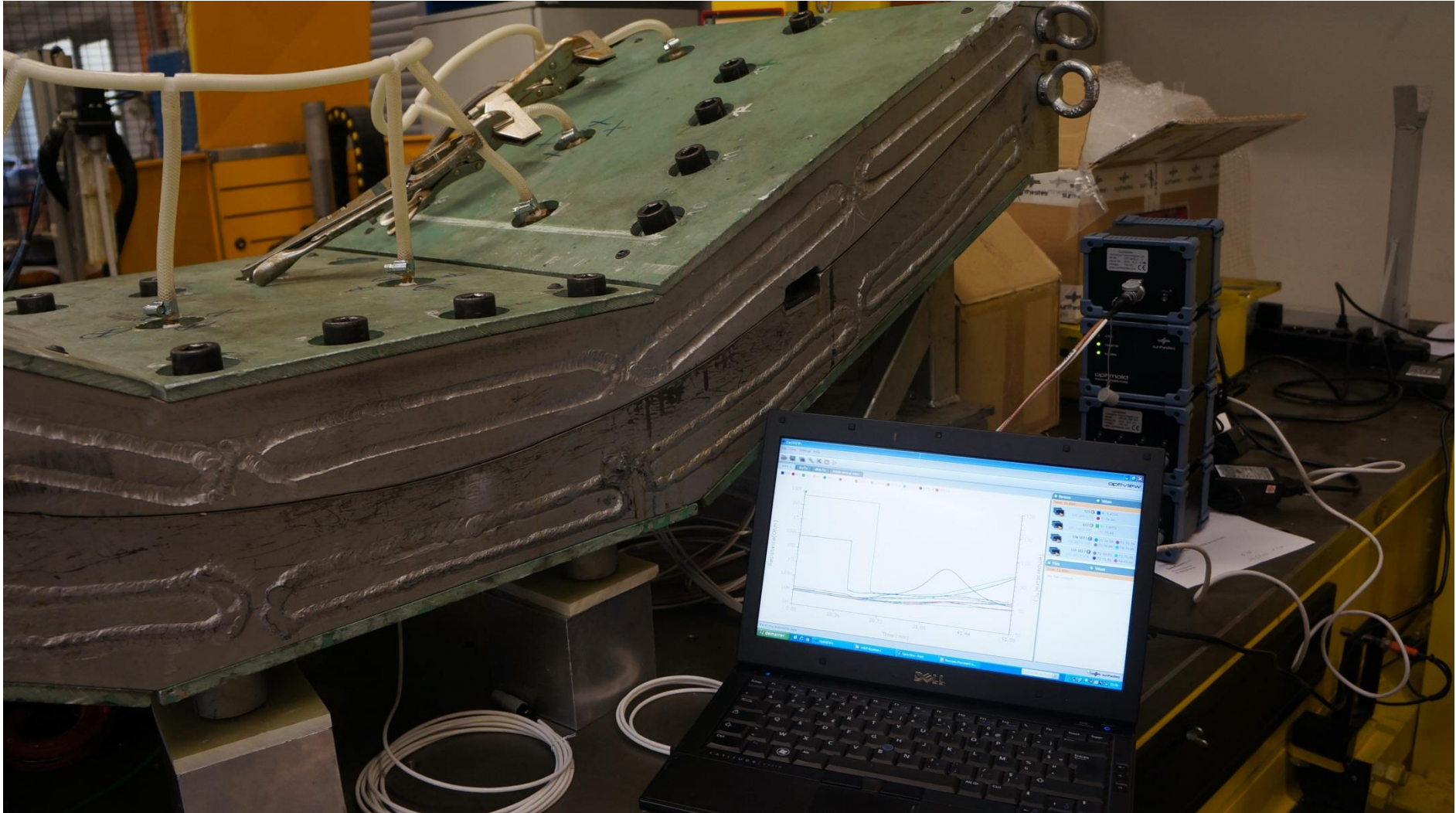
Hutchinson



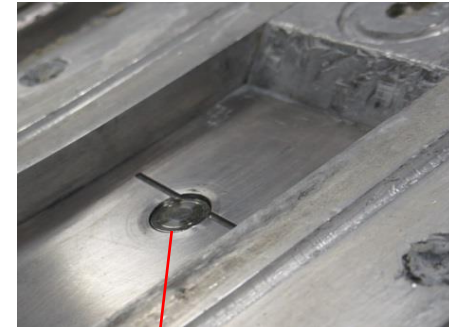
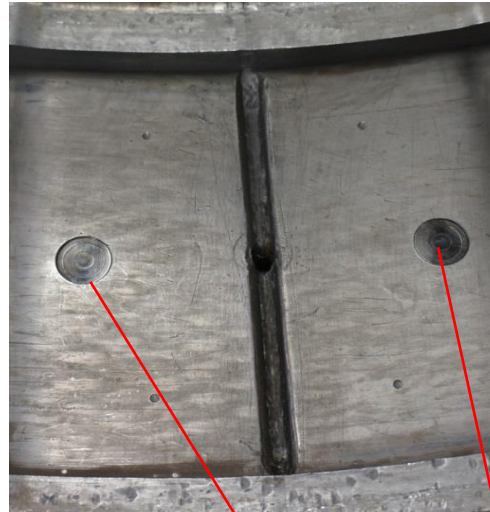
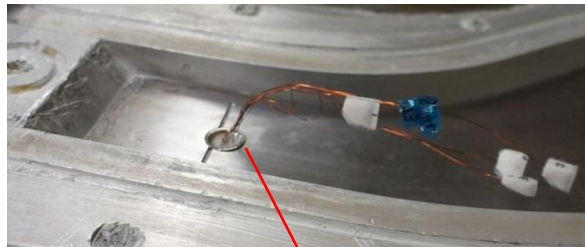
Airborne



RTM mould and process monitoring systems



Hutchinson Demo suspension blade Glassfibre/ epoxy with RTM



8 Embedded sensors
(through-thickness)

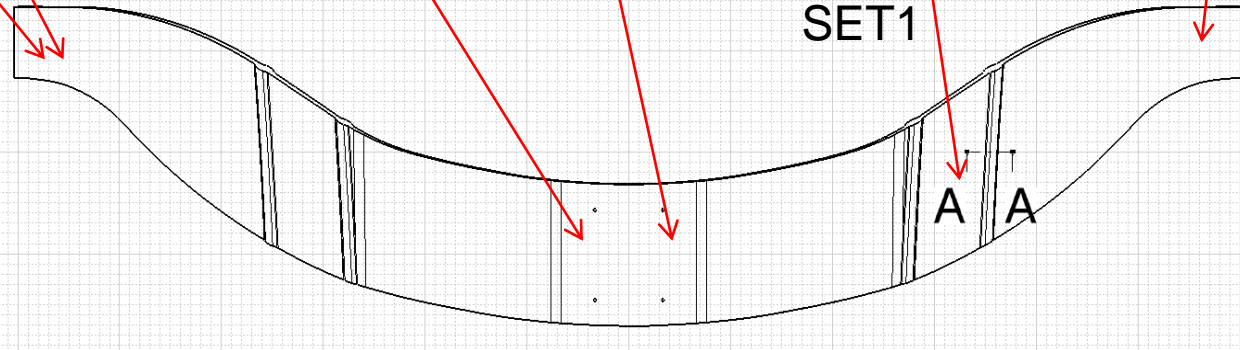
SET2

Durable Sensors
Flow F1 and cure
sensors C1

8 Embedded sensors
(through-thickness)

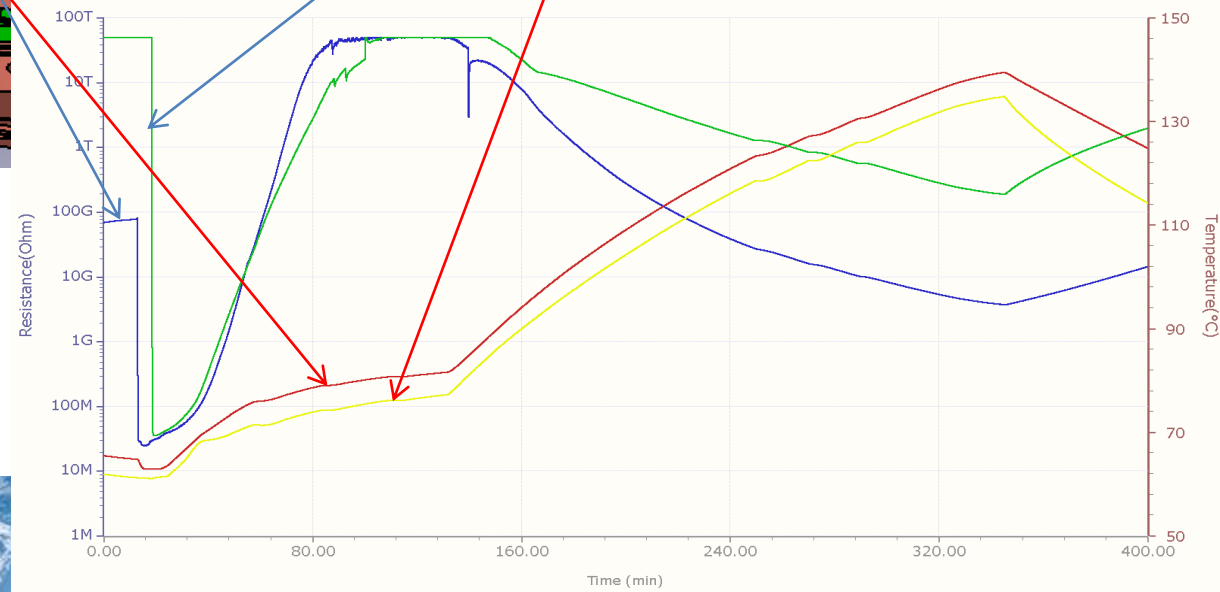
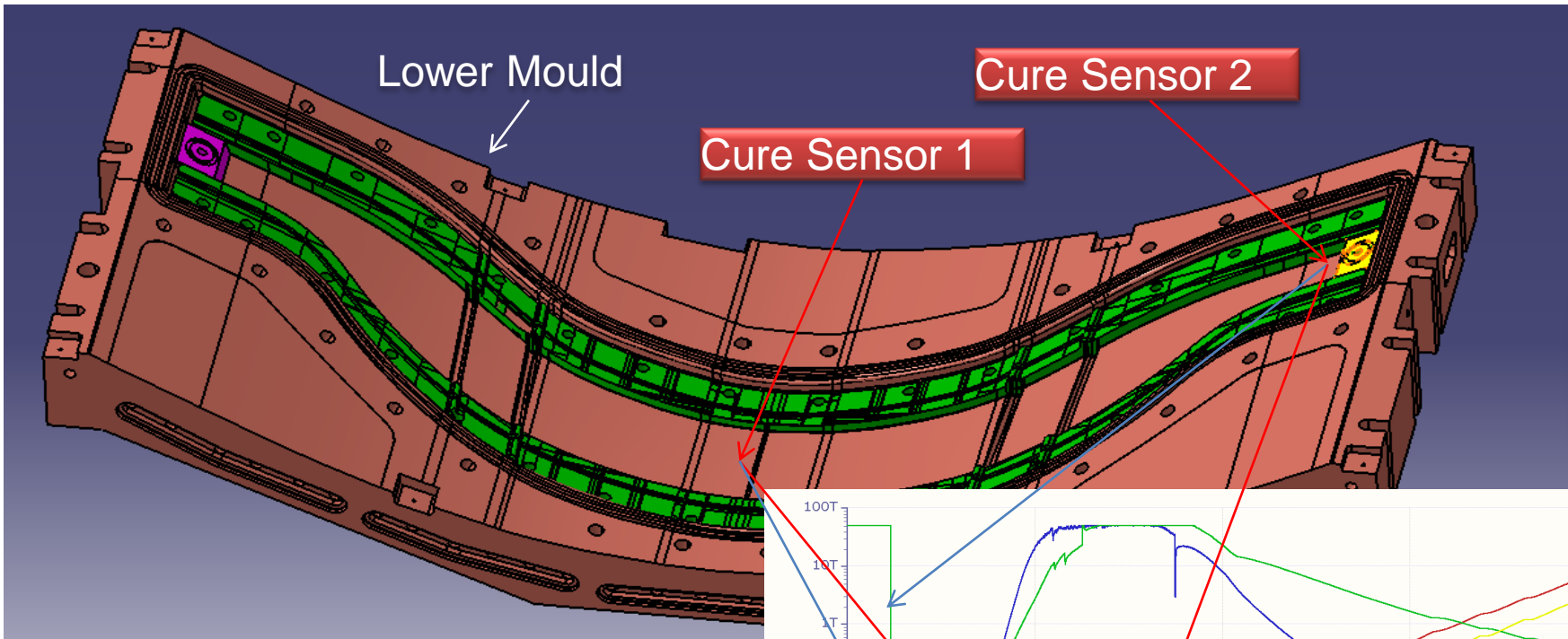
SET1

Durable Cure
sensor C2



Cure sensors position

- 2 cure sensors (cure sensor 1 close to injection point)

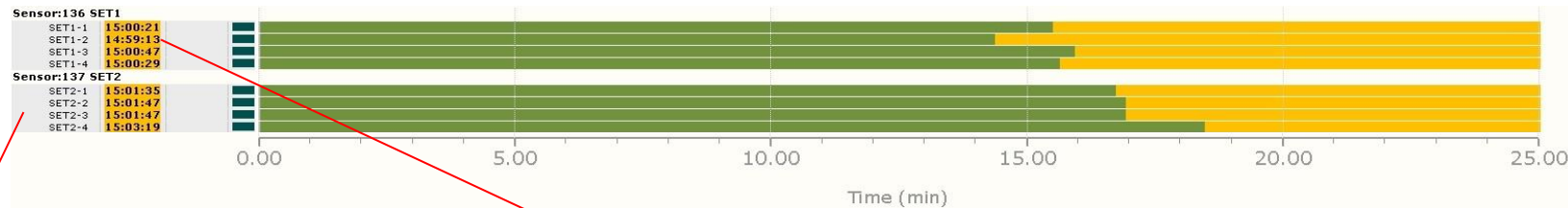


Flow sensors

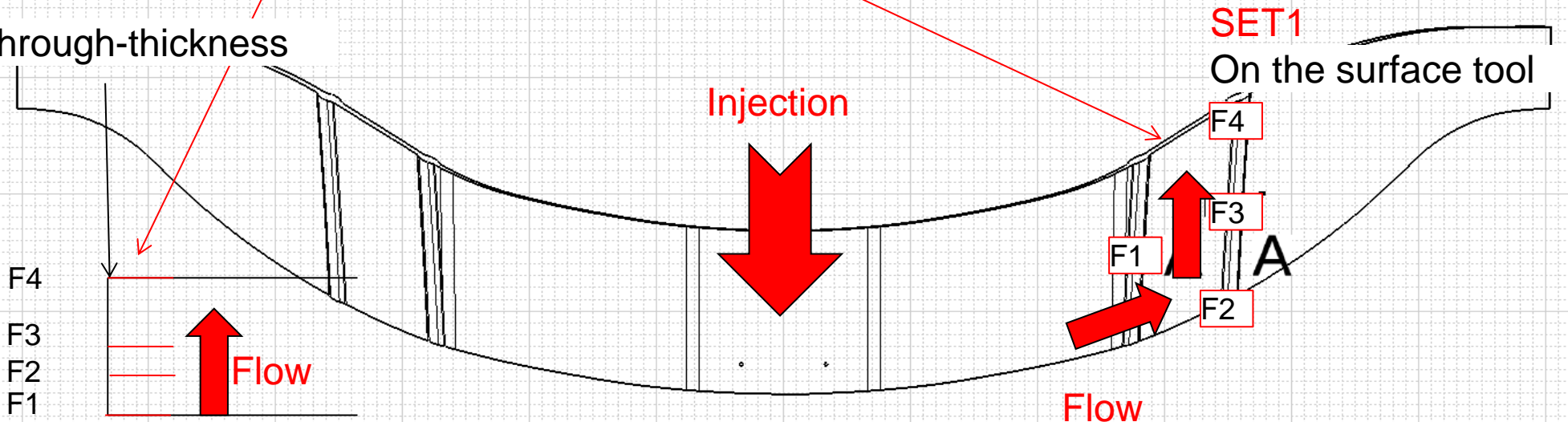
- 8 Resin Arrival (Flowire) connected to 2 Optiflow systems

Through-thickness

Resin arrival time stamps



Through-thickness



Temperature sensors

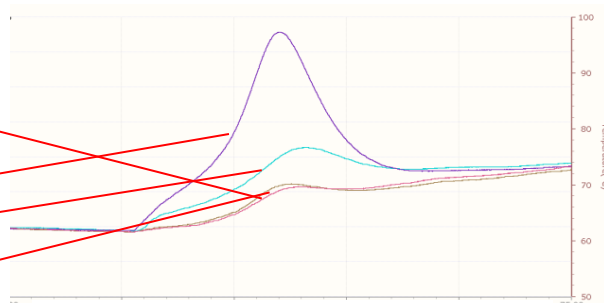
- 8 embedded temperature sensors connected to 2 Optiflow systems

Through-thickness

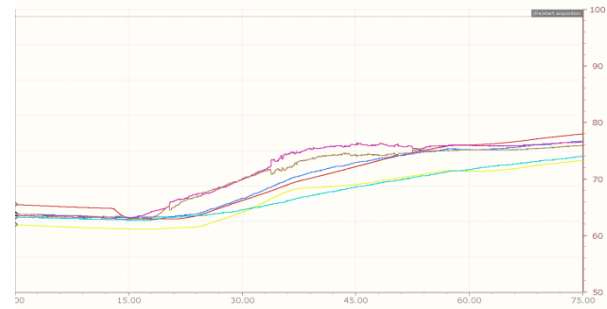
Through-thickness

SET2

T4
T3
T2
T1

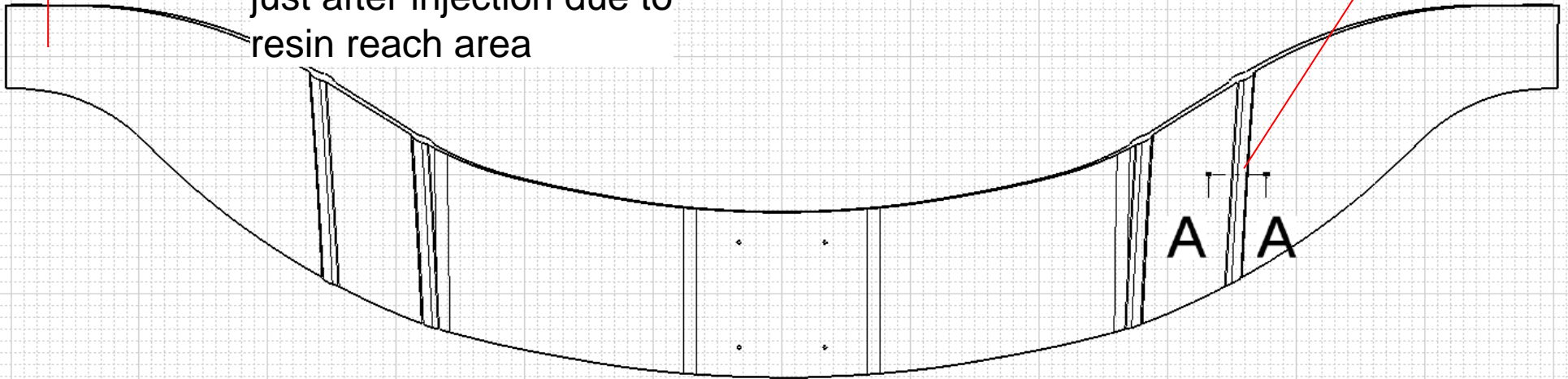
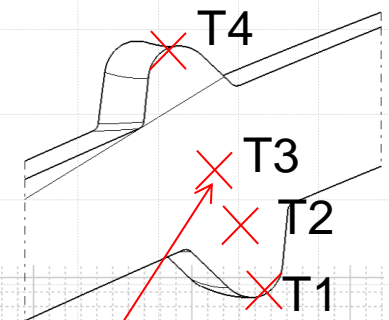


Premature exotherm
just after injection due to
resin reach area

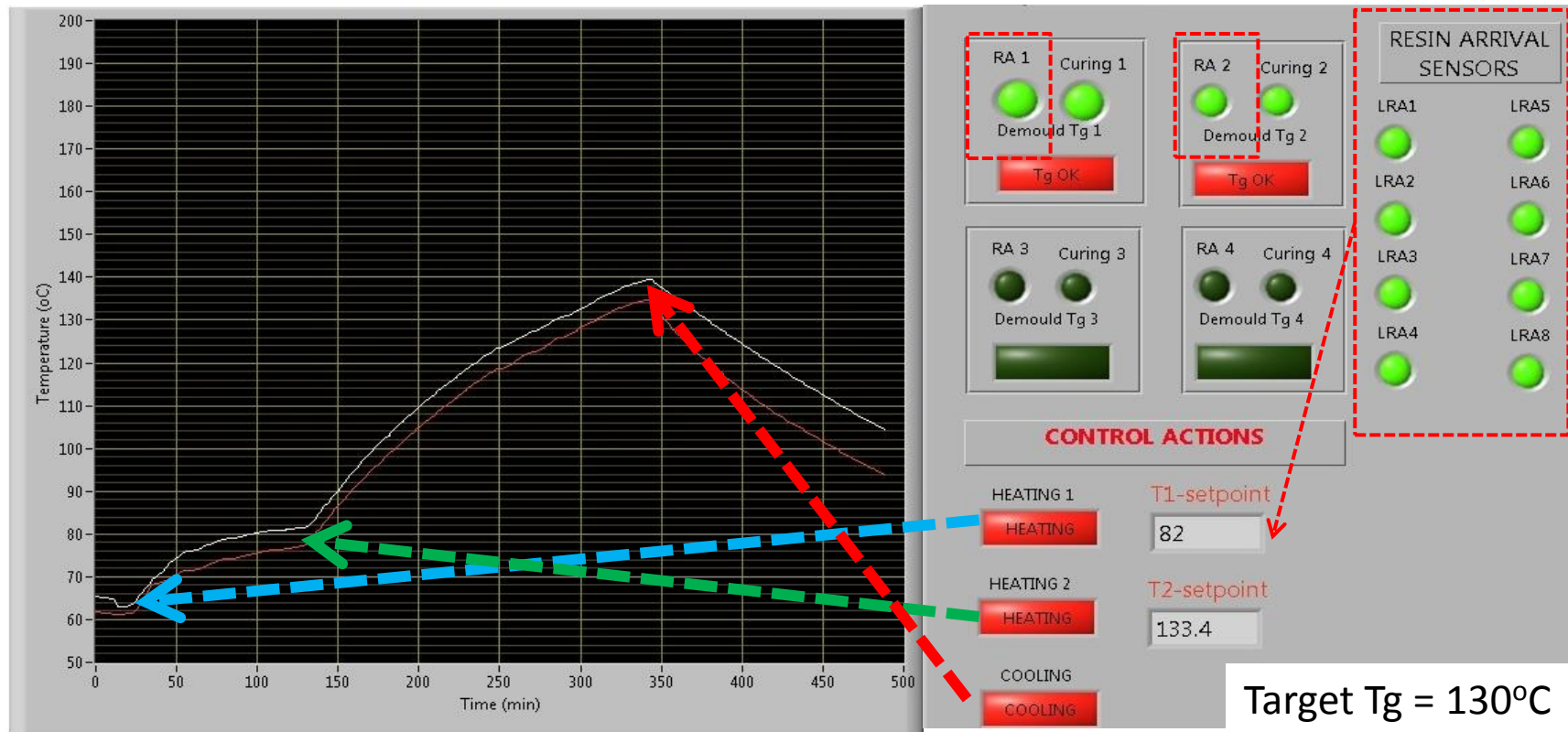


A-A

SET1



Intelligent monitoring and control



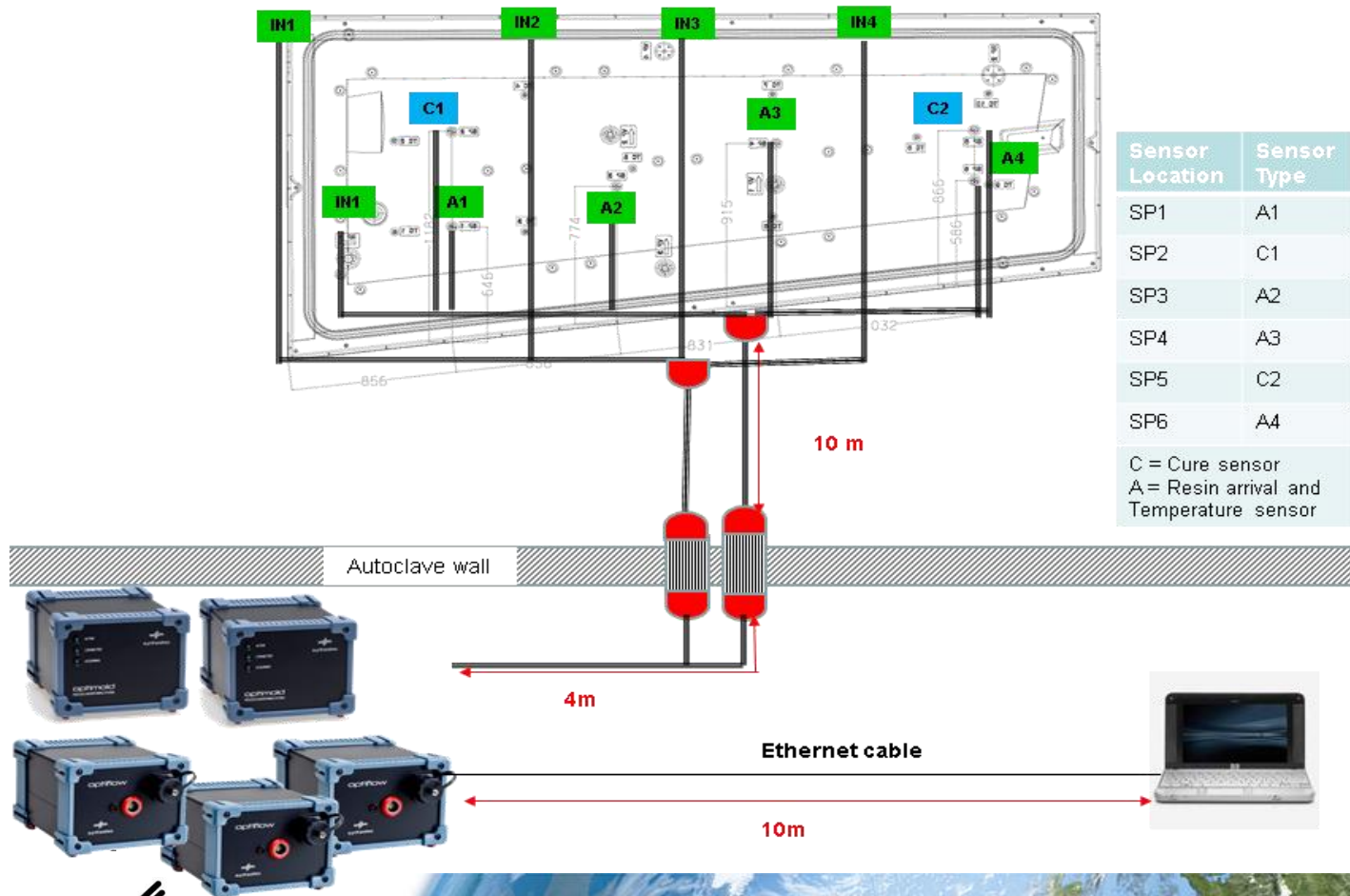
Real-time Tg calculation and demoulding decision based on targeted Tg (target Tg = 130°C)



Bombardier Aerospace Belfast DEMO

Wing Skin Cover

Sensors' location and wiring diagram in and out of the WPU (Wing Production Unit) autoclave

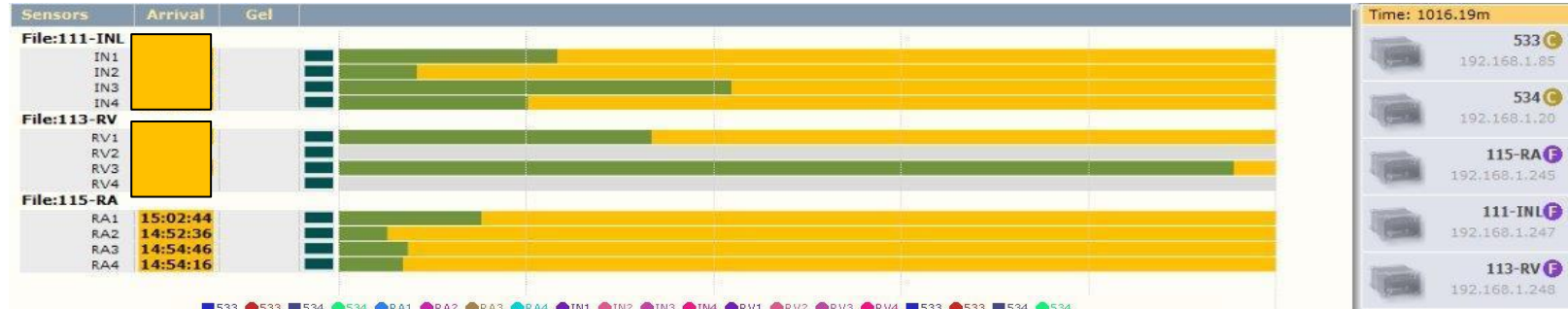


BAB DEMO @ Wing Production Unit Autoclave

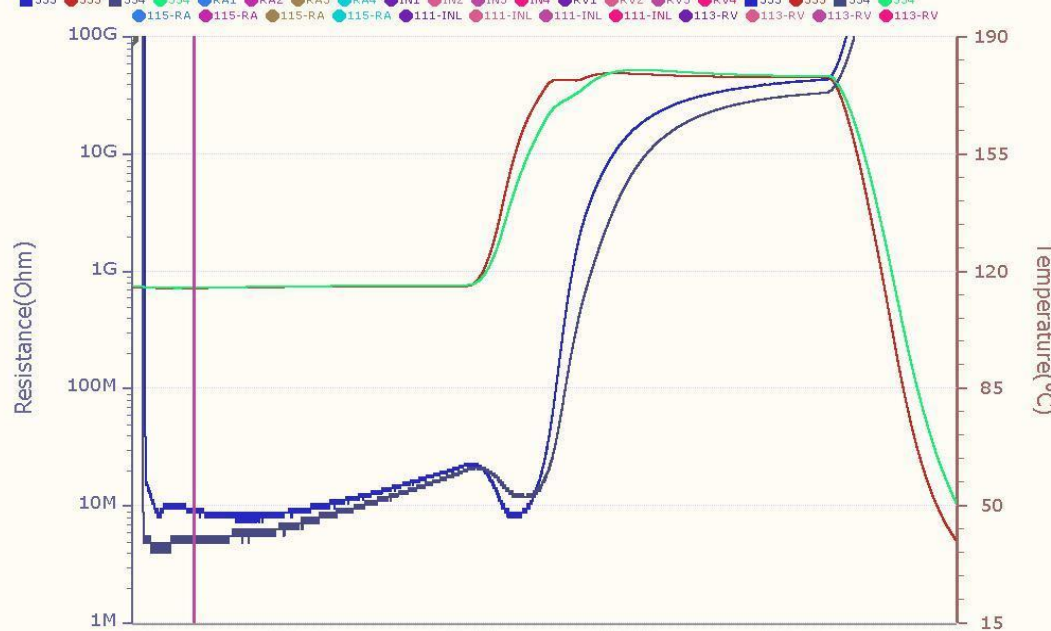
Resin arrival measurements of 4 RA and 6 inline sensors

Resistance and temperature measurements of the 2 cure sensors

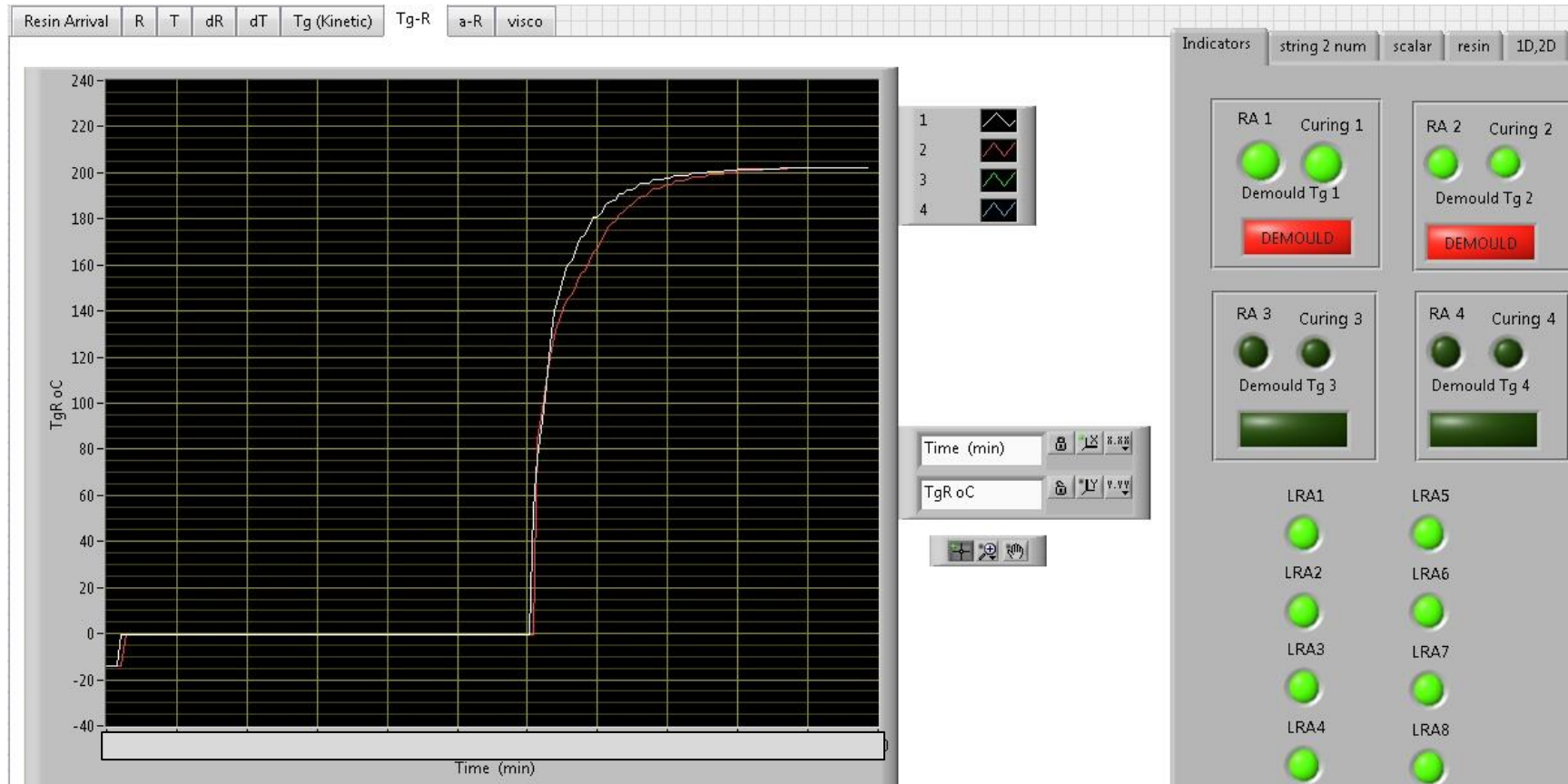
FLOW



VISCOSITY
CURE



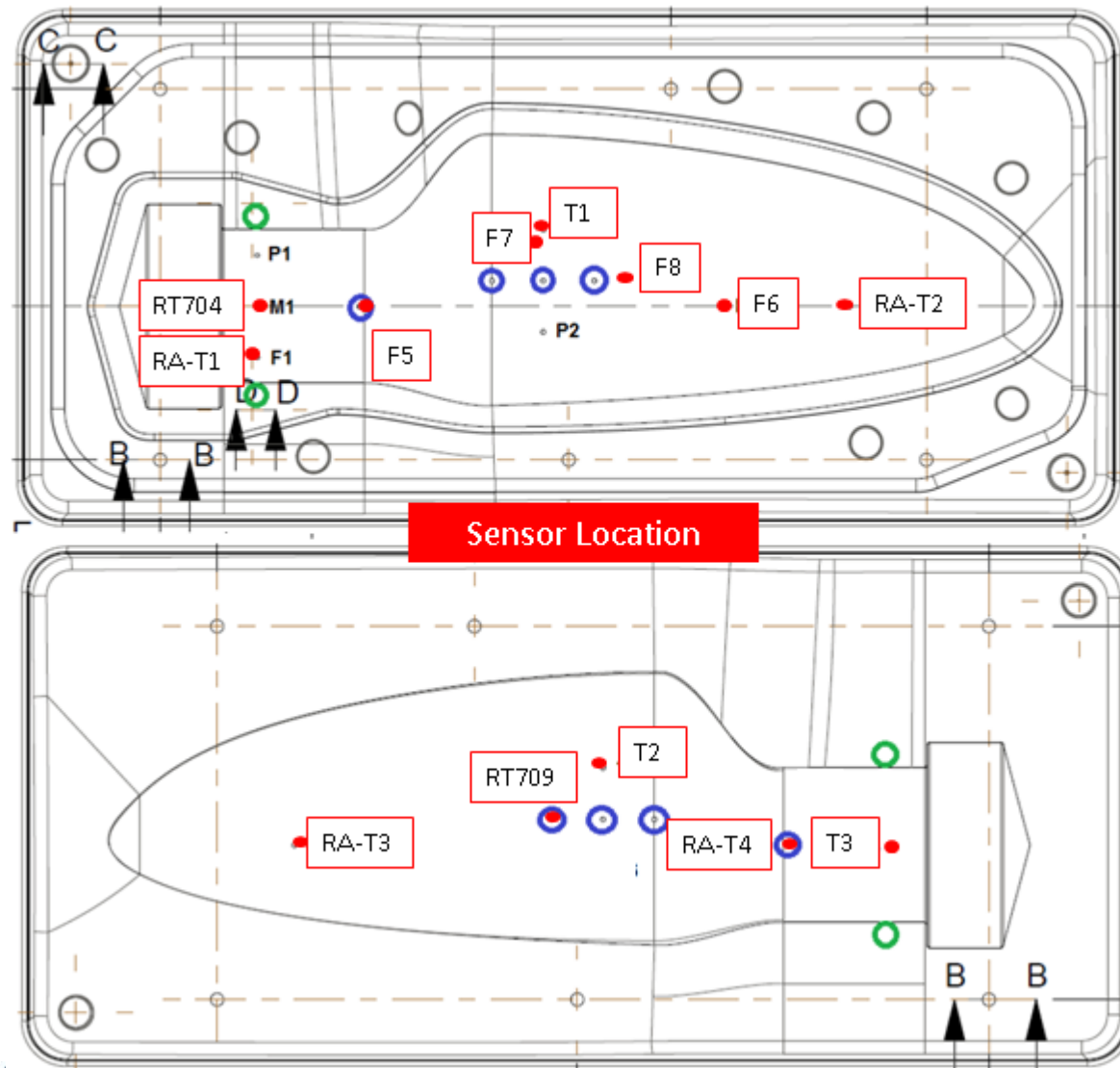
BAB case: Intelligent monitoring and control



Real-time Tg calculation (peak $\tan\delta$) and demoulding decision based on targeted Tg (target Tg = 200°C)



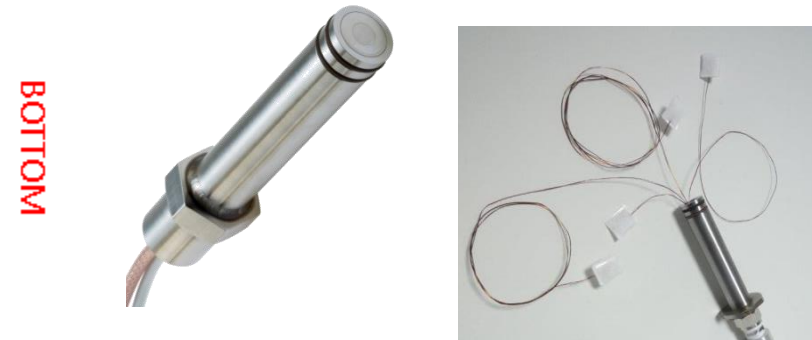
AIR use-case (carbon-epoxy tidal blade)



SENSORS

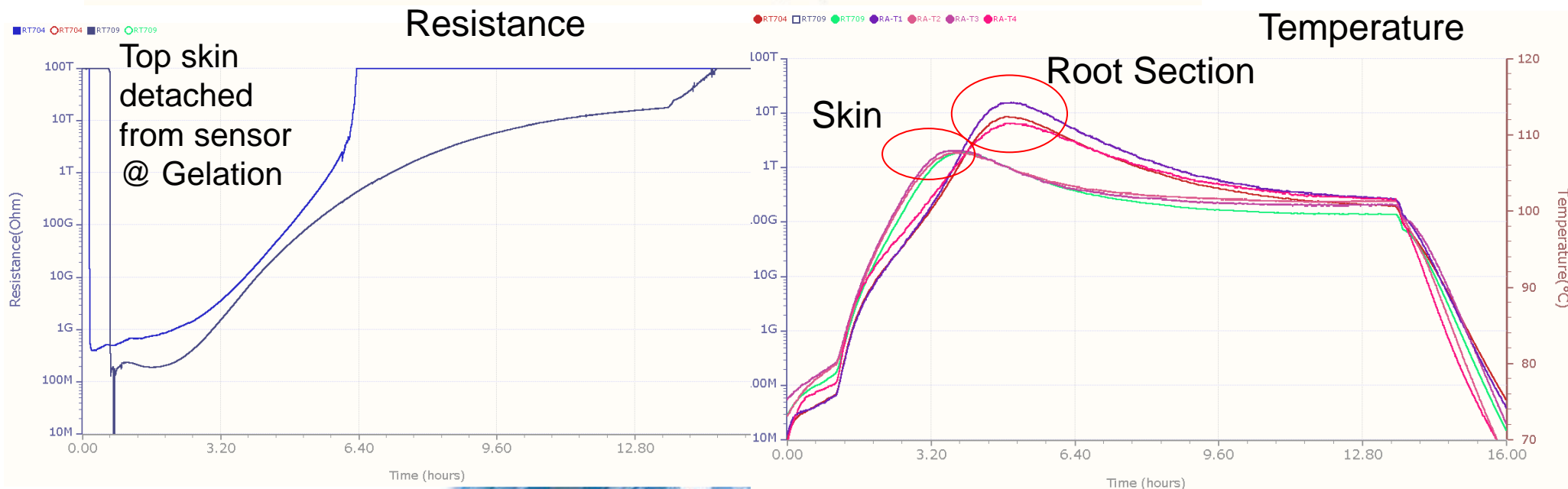
Resin arrival measurements of 4 Durable (RA-T1..4) and 4 Flowire sensors (F5-8)

2 cure sensors (RT704 and RT709) and 2 Pressure sensors (provided by Kistler, integrated into Optiview) (P1 and P2)

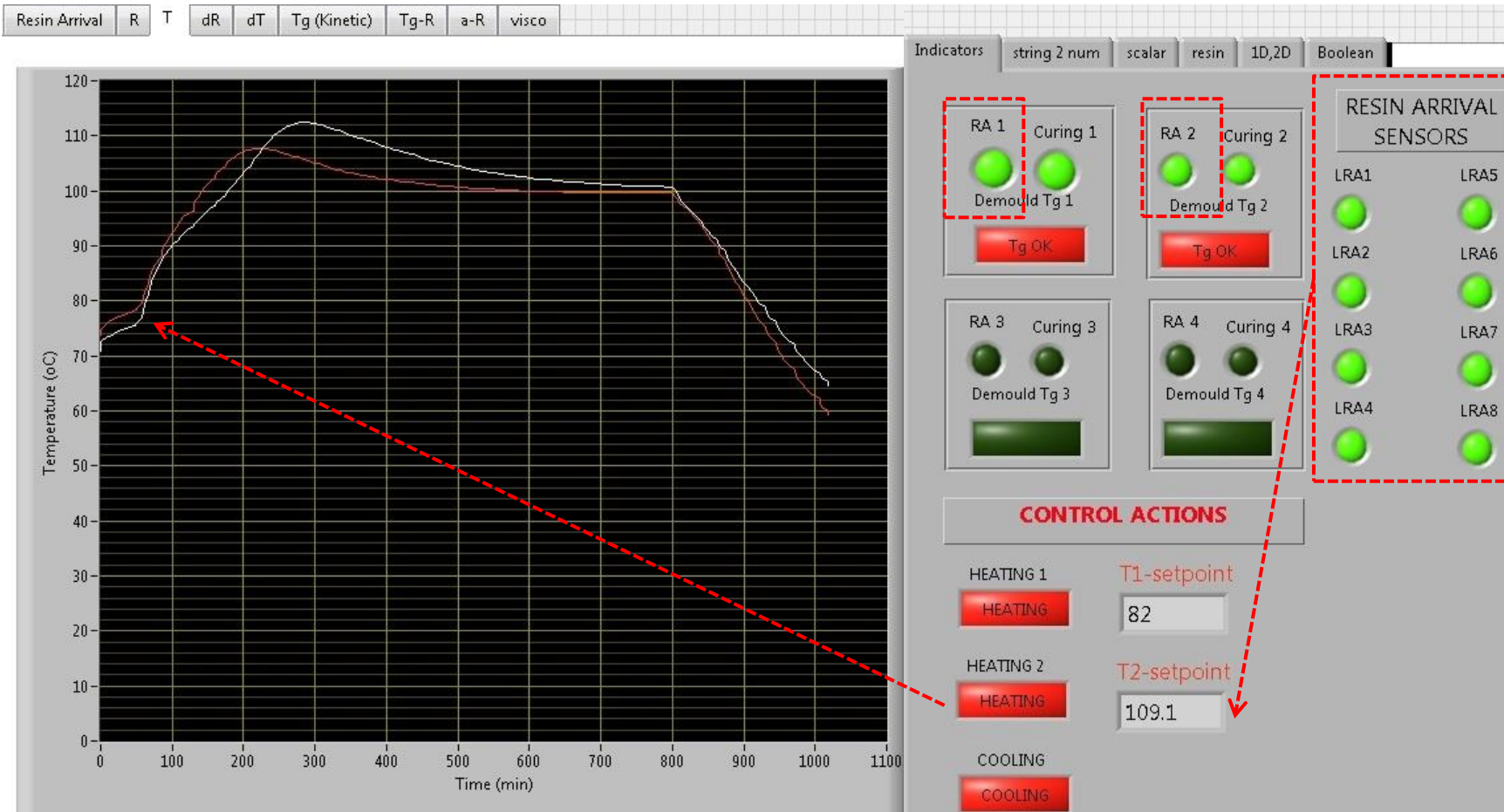


AIR case: Intelligent monitoring and control

Resin Arrival time



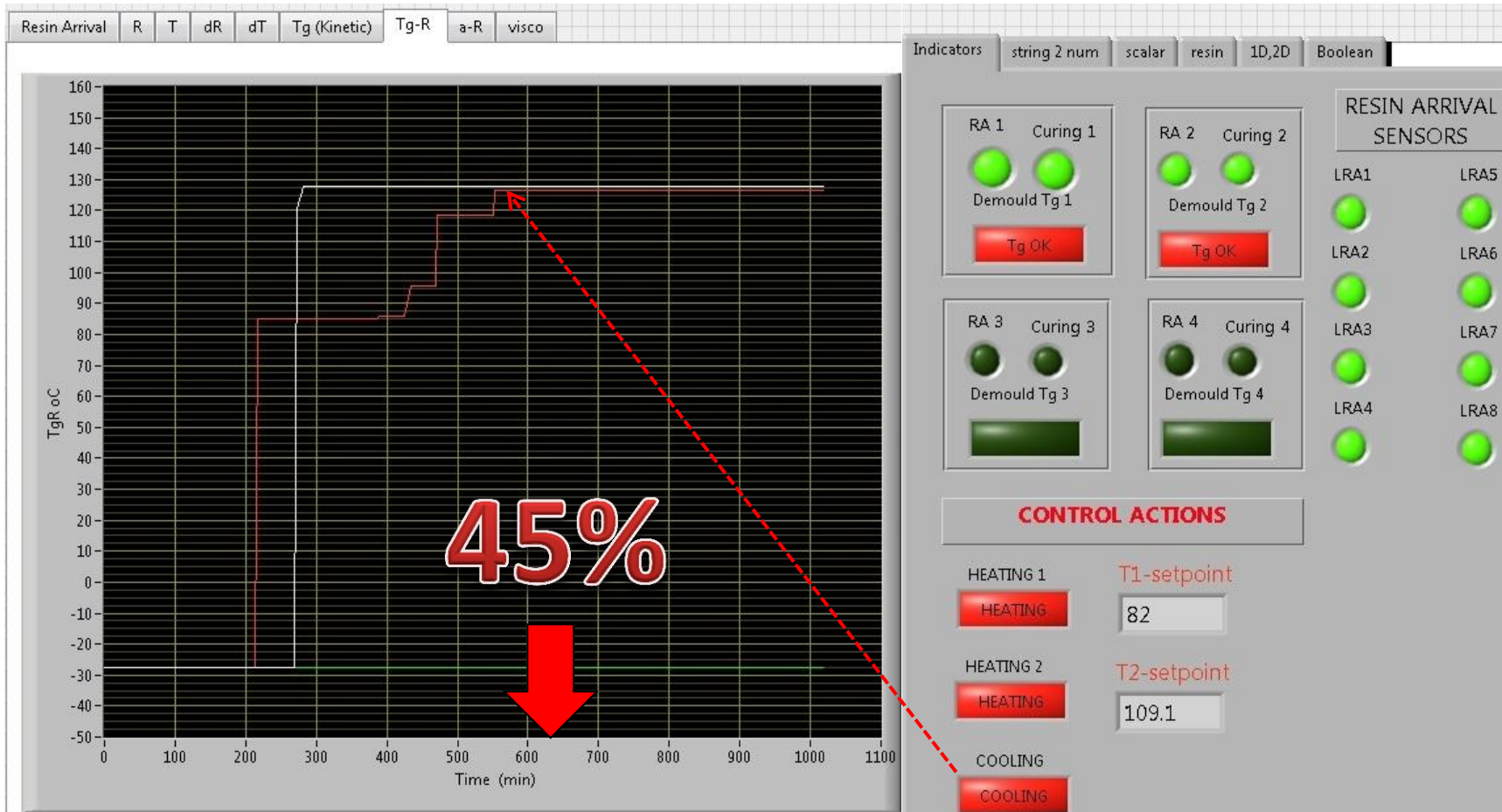
AIR case: Intelligent monitoring and control



Real-time Tg calculation and demoulding decision based on targeted Tg (target Tg = 126°C)



AIR case: Intelligent monitoring and control



Real-time Tg calculation and demoulding decision based on targeted Tg (target Tg = 126°C)



Conclusions

- The Intelligent Process Monitoring and Control Platform developed in ECOMISE is a reliable solution for automating and optimising composites manufacturing
- The platform can provide reliable solutions for online and offline optimization of the process
- The adaptation and tuning of the platform to the process-specific needs can be done on-site so no costly lab-scale trials are necessary.
- A speed-up of more than 30% with respect to conventional processing can be achieved.
- Further benefits from the use of this technology from the development phase.
- Industrial applications in Aerospace, Automotive, Energy and potential for customized solutions according to customers' needs.





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Many Thanks to our Customers and Collaborators around the world for trusting our Technology



Dedicated to innovation in aerospace

