CleanSky2
LPA - WP 1.4.4

CS2 Composite Materials and Manufacturing Workshop

HLFC-WIN: Suction Rib Infusion – The Digital Infusion Center in Action

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HLFC-WIN Introduction

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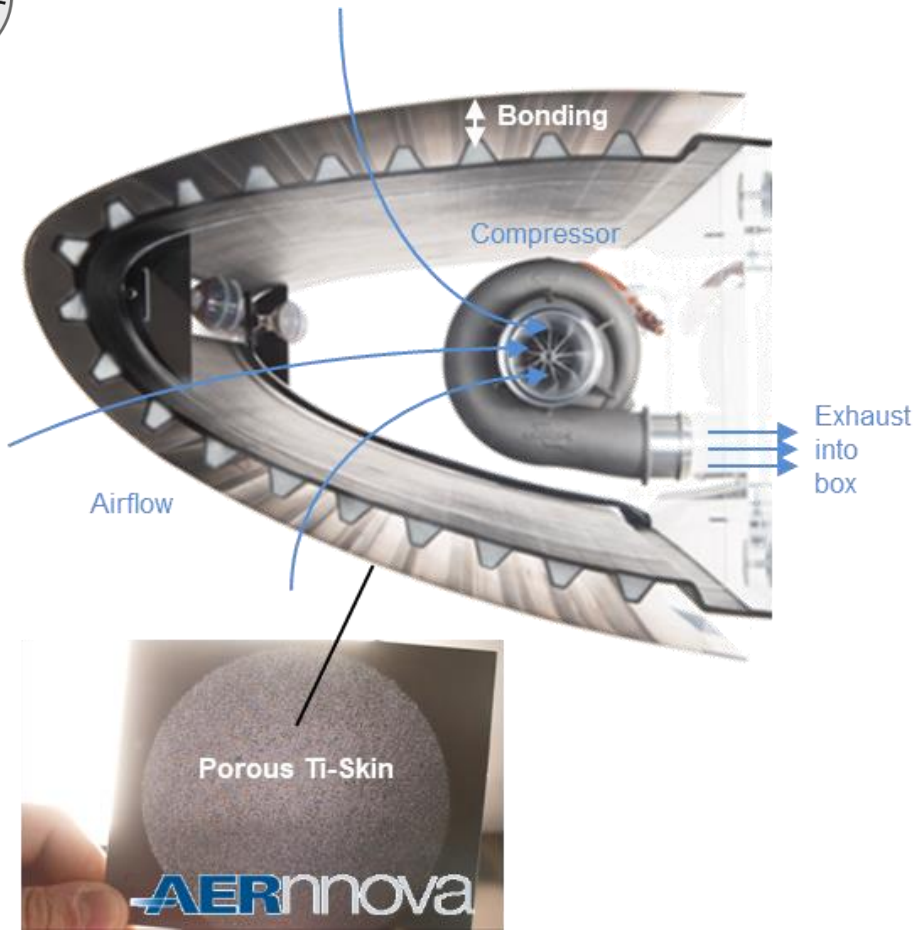
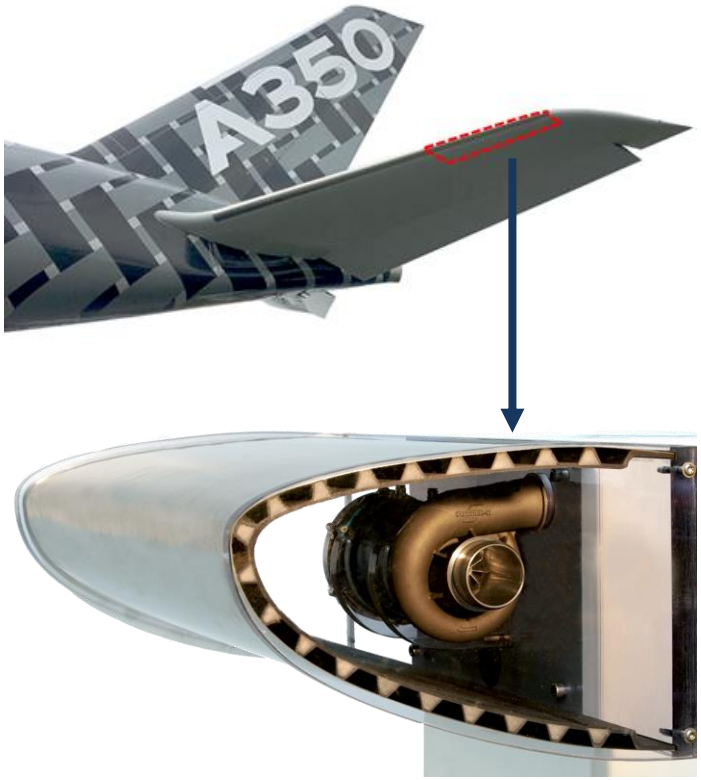
LPA WP 1.4.4 HLFC-WIN Introduction

- Contributing Project: HLFC-HTP (CS2 WP 1.4.1)

Technology Readyness Level 4

HLFC (Hybrid Laminar Flow Control) **on HTP** (Horizontal Tail Plane)





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LPA WP 1.4.4 HLFC-WIN Introduction

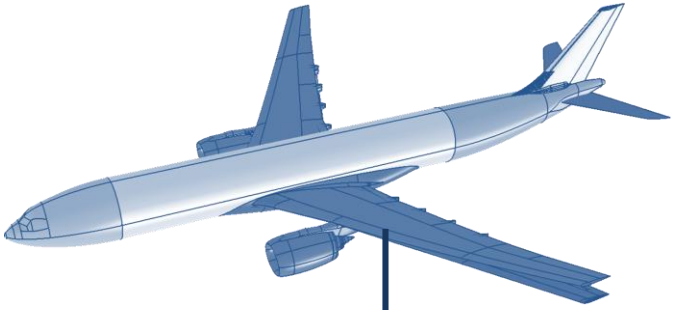
- **Target Aircraft Configuration:**

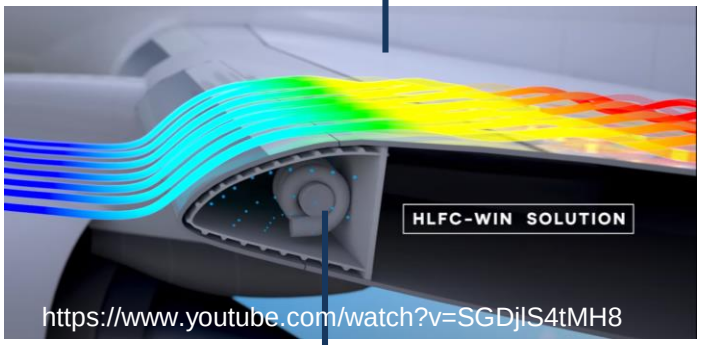
  XRF1 with novel laminar wing

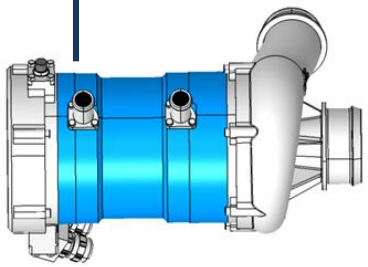
- **Laminarisation Approach:**

  HLFC (**H**ybrid **L**aminar **F**low **C**ontrol)

- **Innovation within HLFC-WIN:**
  - Modular wing leading leading edge
  - Exchangeable Suction Glove
  - Contact free inductive de-/anti-icing
  - Active suction (electrical compressors)
  - No-pipe approach with distributed compressors
  - <u>Compressors are integrated in modified leading edge ribs → **"Suction Ribs"**</u>







Picture: Fischer EMTC 120 Air

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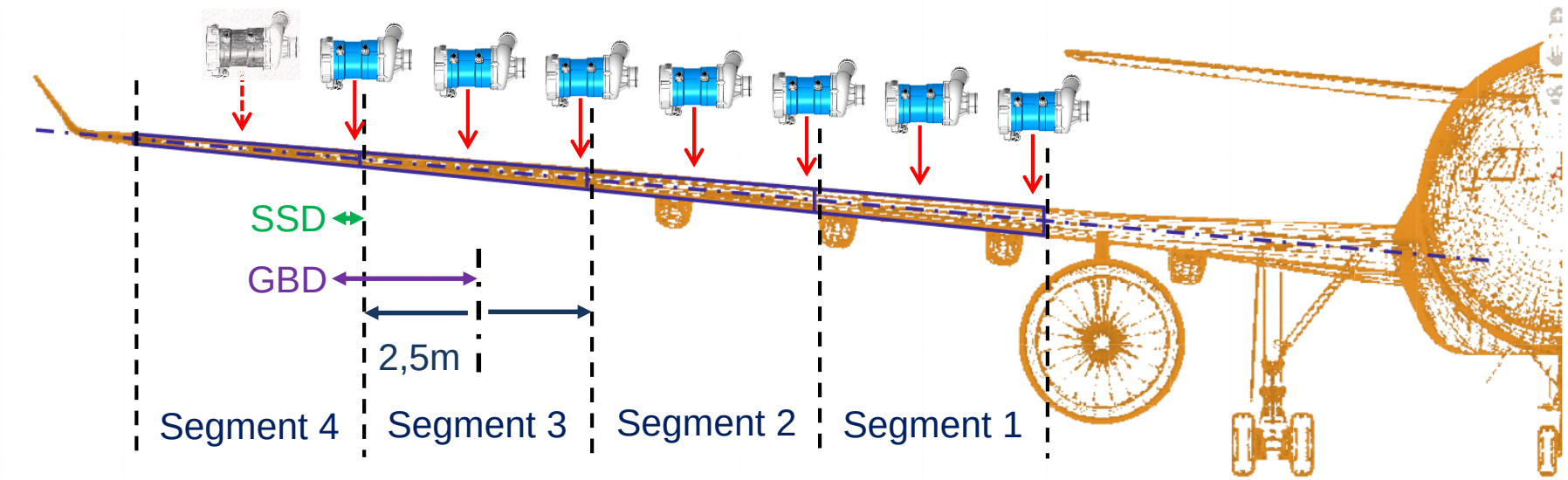
LPA WP 1.4.4 HLFC-WIN Introduction

- The outer wing is divided into four technically similar, independent segments
- Compressors (two per segment) are distributed along the wing
- Eliminated pipe friction leads to sinificantly reduced power consumption



SSD: Small Scale Demonstator (TRL3)

GBD: Ground Based Demonstrator (TRL4)

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HLFC-WIN Suction Rib SSD Design

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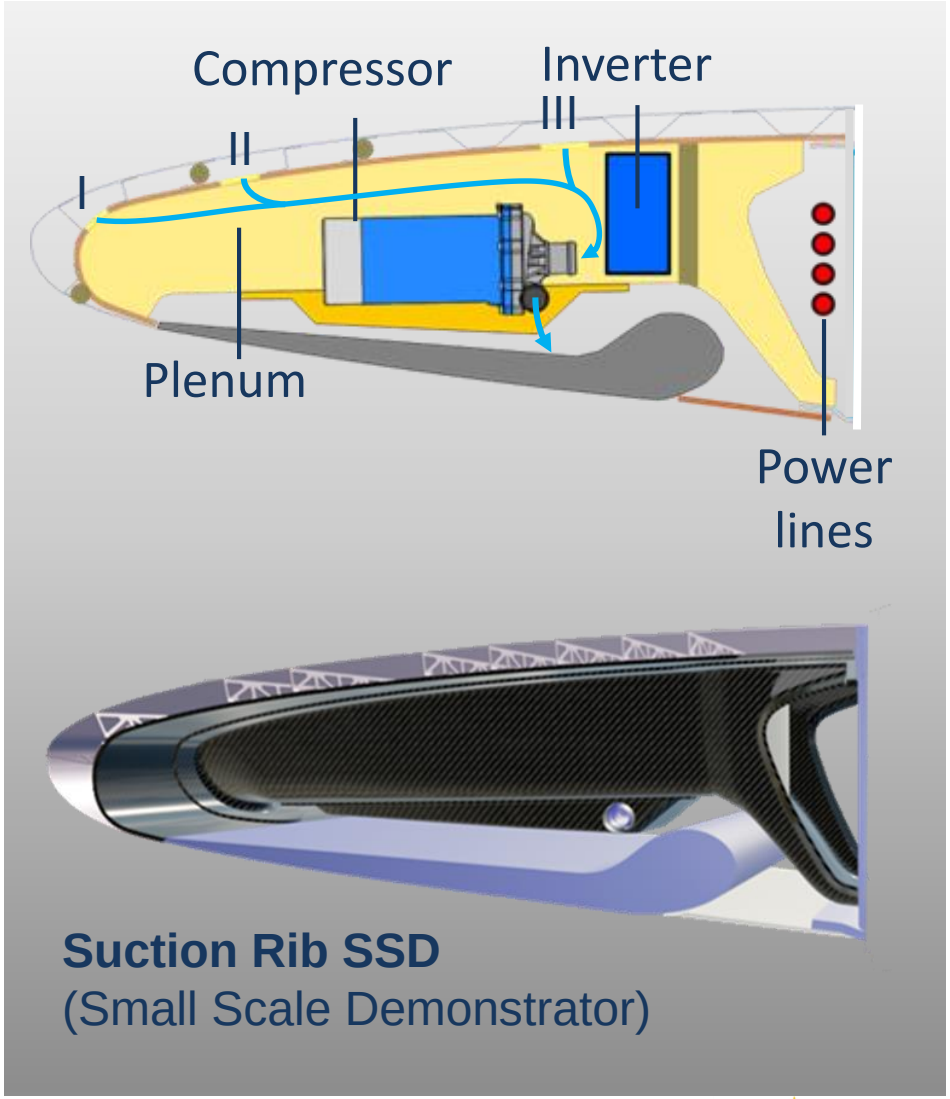
HLFC-WIN Suction Rib SSD Design

- **Basic Suction Rib Setup**
  → Suction System
  - Three (I,II,III) glove chambers with individual pressures
  - Low pressure plenum chamber in suction rib
  - Compressor with adjustable air flow
  - Simple compressor outlet into the Krüger chamber (option)
  - Airflow utilized to cool compressor and inverter



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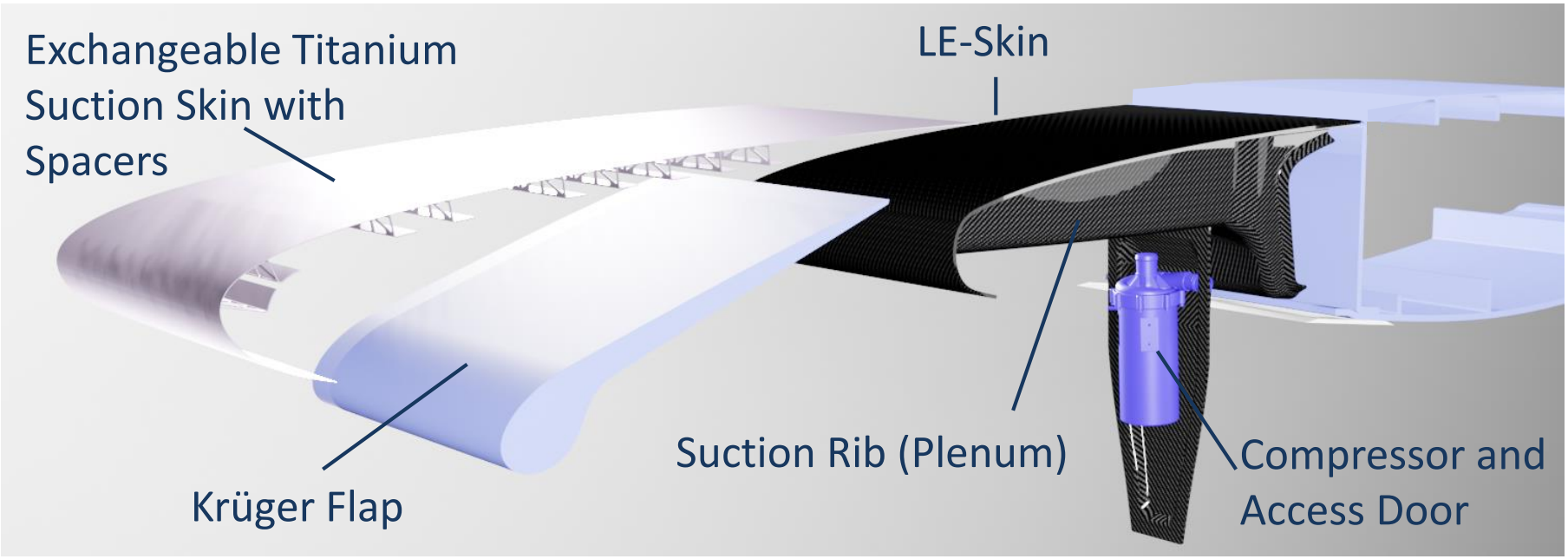
HLFC-WIN Suction Rib SSD Design

- **Basic Suction Rib Setup → Structural Elemets**
  - Erosion resistant, exchangeable microdrilled Titanium glove with spacers
  - Light weight CFRP leading edge skin and suction rib
  - Easy to service plug-and-play compressor mounting



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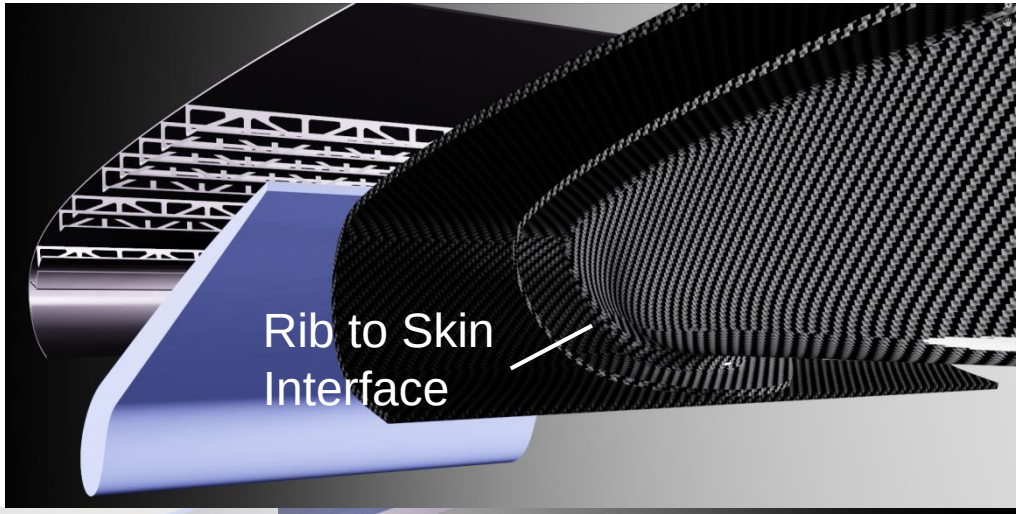
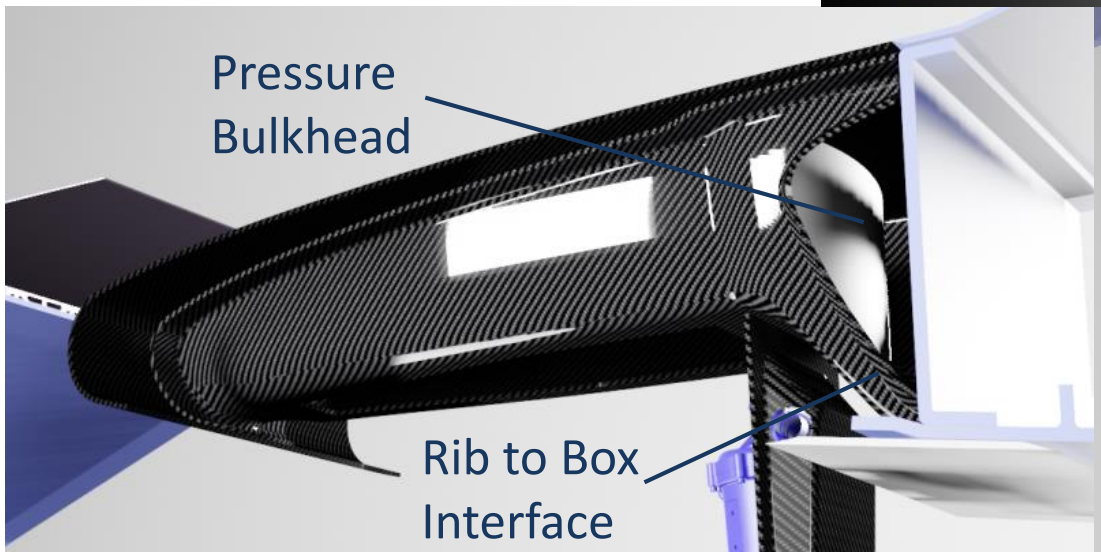
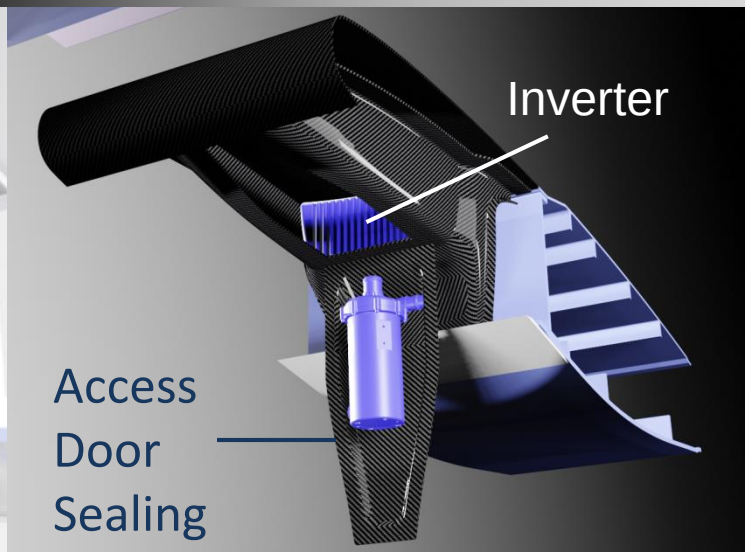
HLFC-WIN Suction Rib SSD Design

- **Manufacturing Challenges**
  - Interface complexity
  - Double curvature
  - Back-cuts
  - Required sealing face accuracy







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HLFC-WIN Suction Rib SSD Manufacturing

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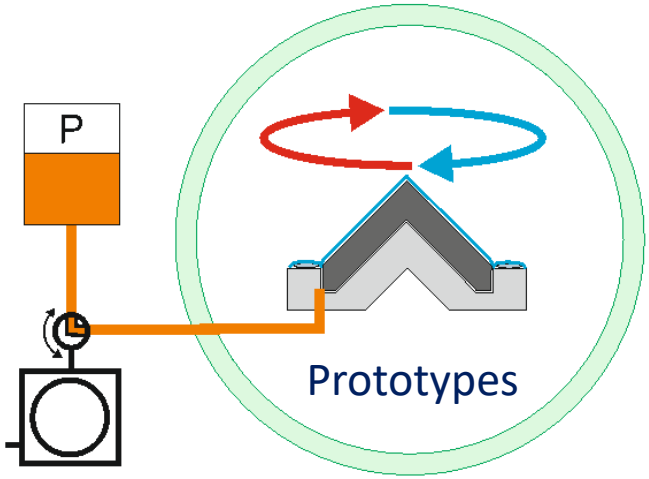
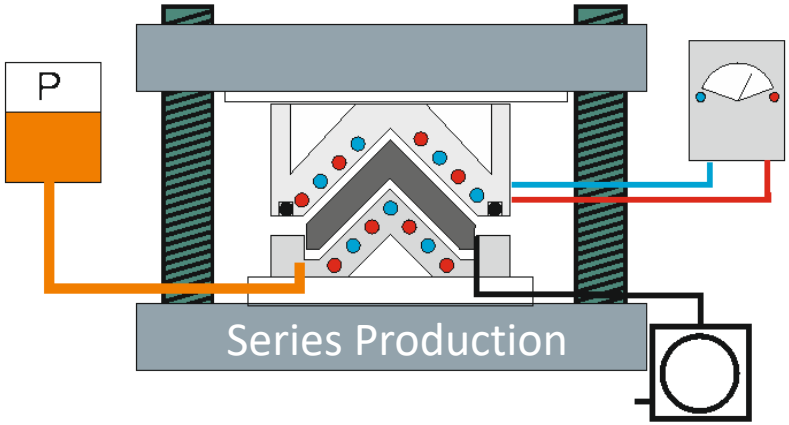
HLFC-WIN Suction Rib SSD Manufacturing

- **Manufacturing Approach**
  - Autoclave infusion <u>for prototypes</u> → Low Tooling Costs → Flexibility
  - RTM (Resin Transfer Moulding) <u>for later series production</u> → Energy Efficiency → Cycle Time
  - Pressure (P) assisted process → Low Void Content → Cycle Time



Autoclave Infusion / Open Mould



Press RTM / Closed Mould

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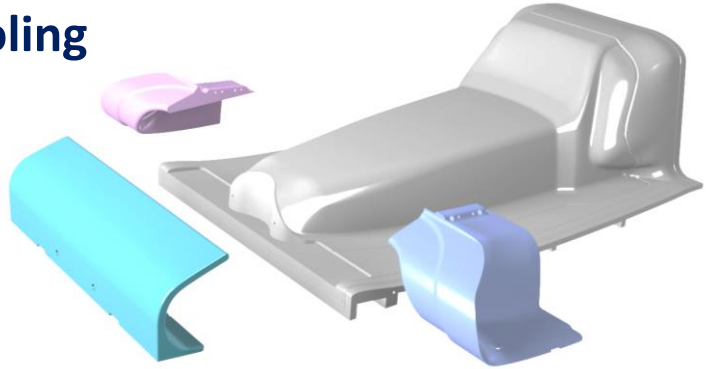
HLFC-WIN Suction Rib SSD Manufacturing

- **Hybrid (open/closed mould) Suction Rib Tooling**
  - Modular preforming and infusion mould
  - Closed mould elements in front section
  - Base tool machined from single block to ensure vacuum tightness
  - Detailed backcut/demoulding simulation
  - Integrated ports for resin and vacuum



Aluminum

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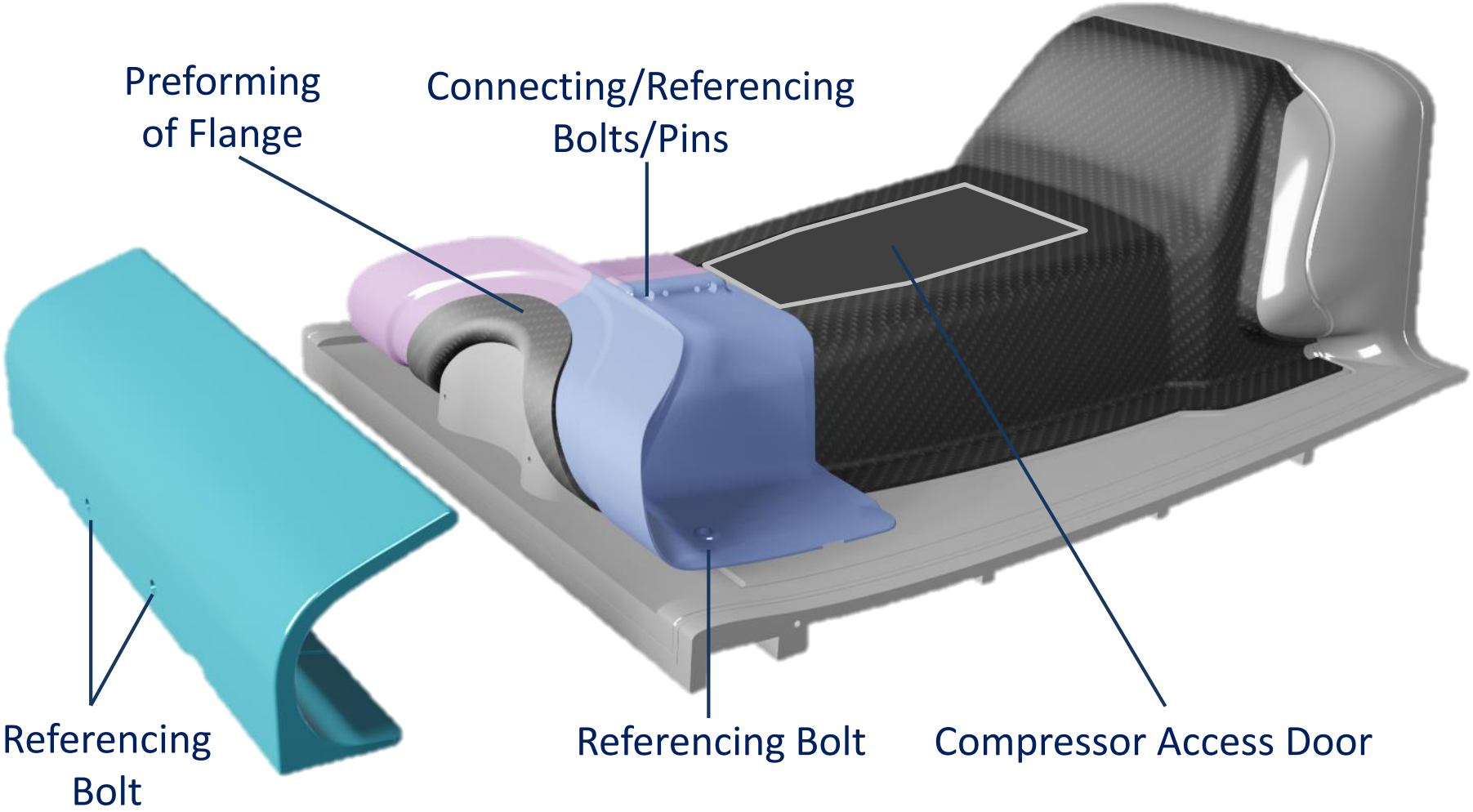
HLFC-WIN Suction Rib SSDManufacturing

Preforming Approach (Hexcel G0926 with binder)



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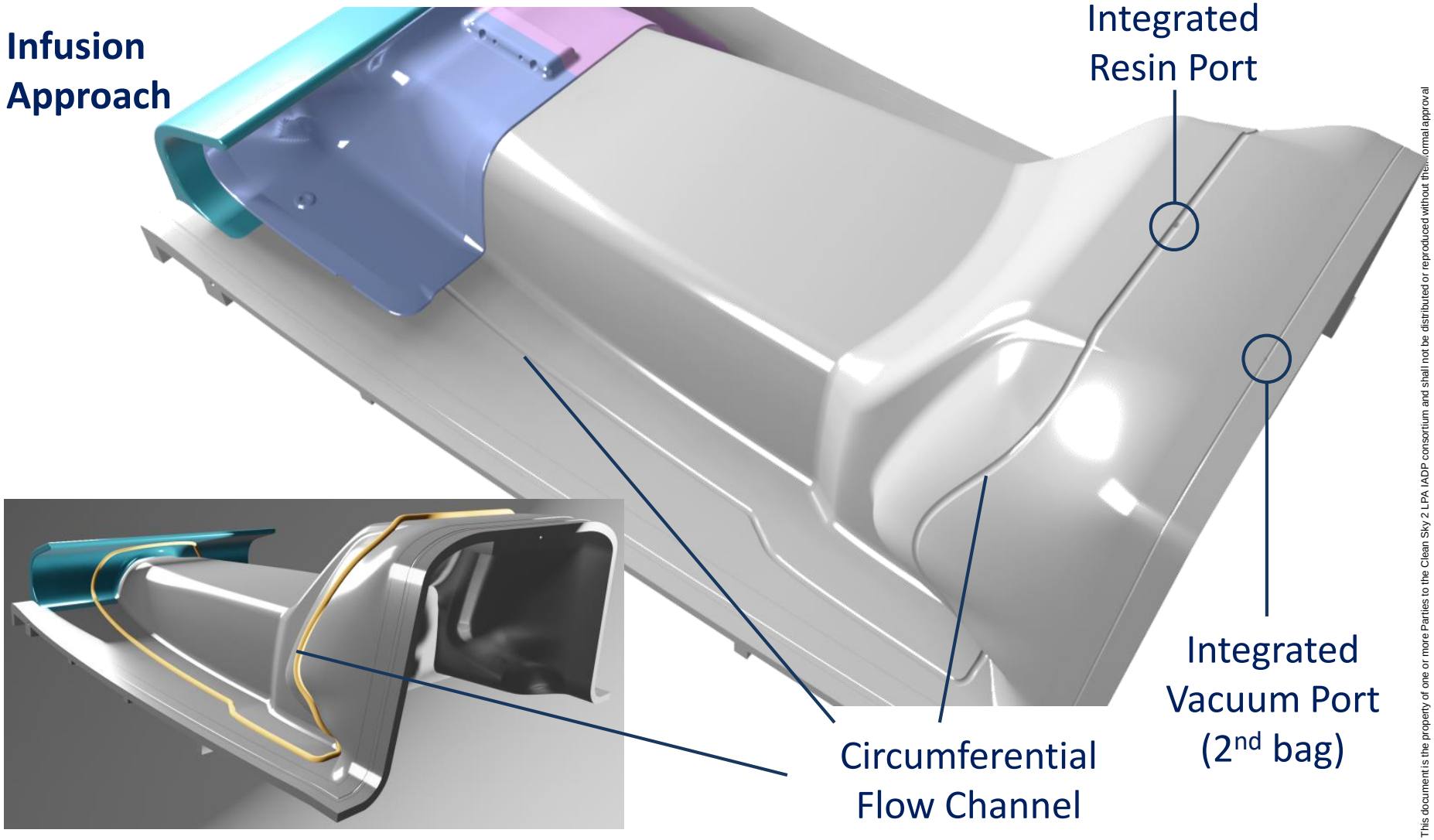
HLFC-WIN Suction Rib SSD Manufacturing

Infusion Approach



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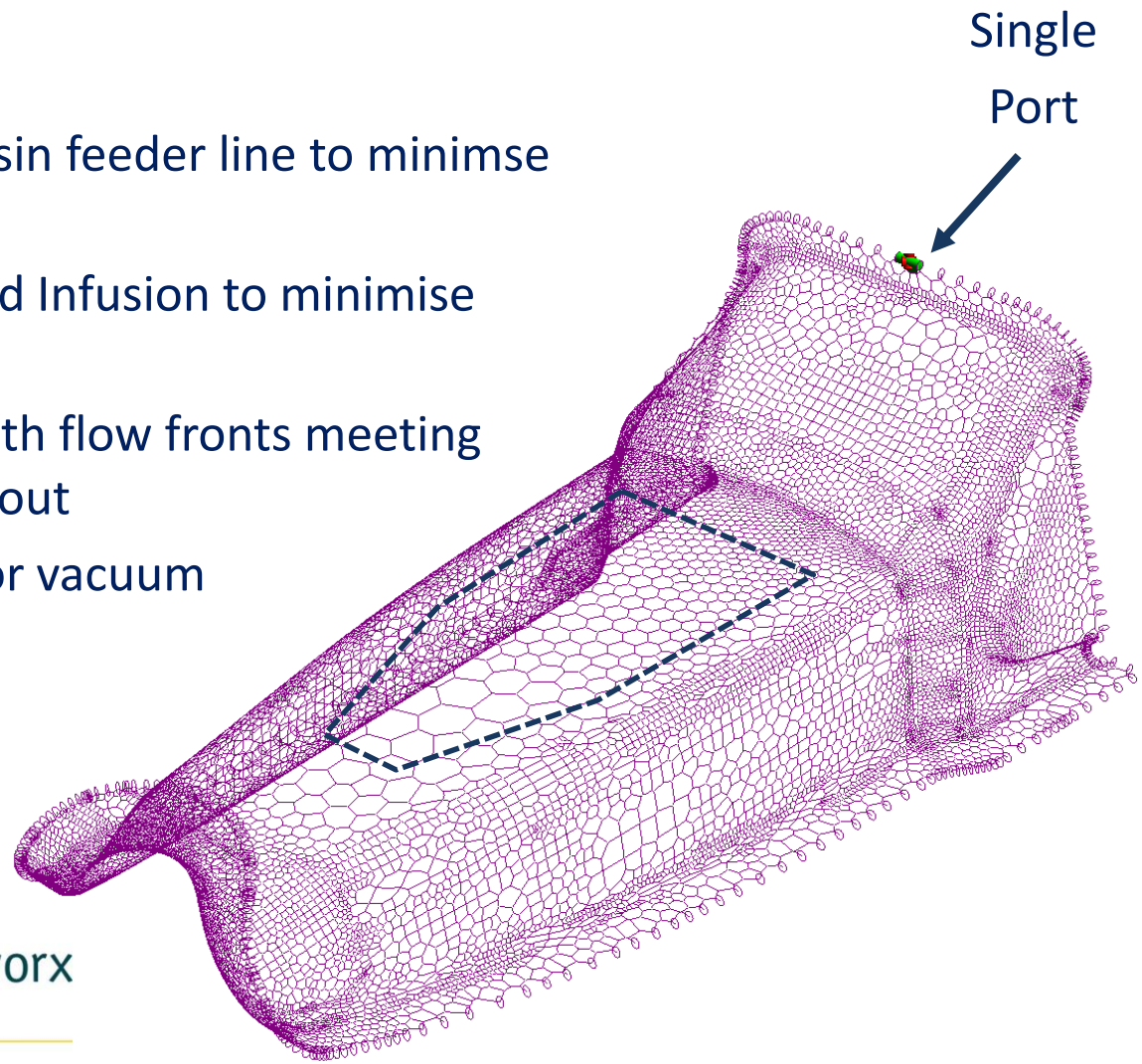
HLFC-WIN Suction Rib Manufacturing

- **Infusion Strategy**
  - Circumferential resin feeder line to minimse flow length
  - Pressure supported Infusion to minimise infusion time
  - Robust infusion with flow fronts meeting at access hole cut out
  - Single Port used for vacuum and infusion



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Digital Infusion Center

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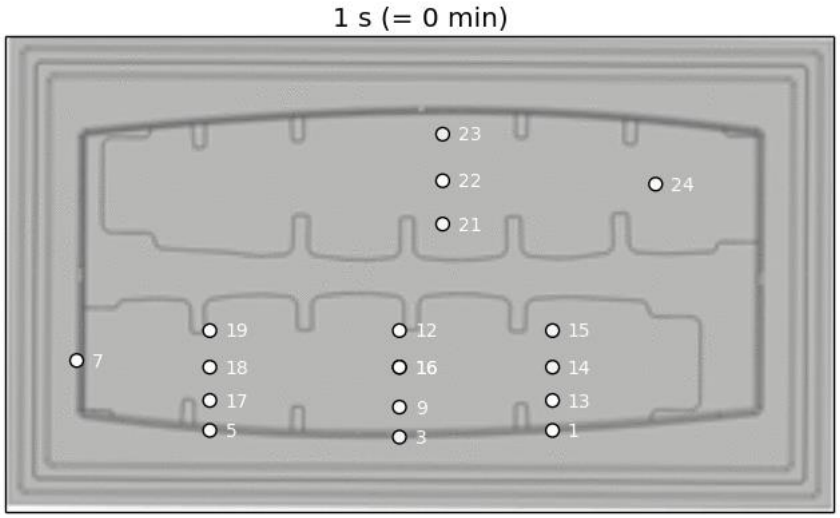
Digital Infusion Center

- Contributing Projects: LOCOMACHS (EU, FP7)

  Autoclave Infusion Wing Rib

  – Sensor controlled Infusion
  – Control of gelation and glass transition
  – Adjustment of fibre content (thickness)
  – Minimisation of PID scatter
  (PID: Process Induced Deformation)

Sensors: - US-Sensors (Transmision)
- US-Sensors (Impuls-Echo)



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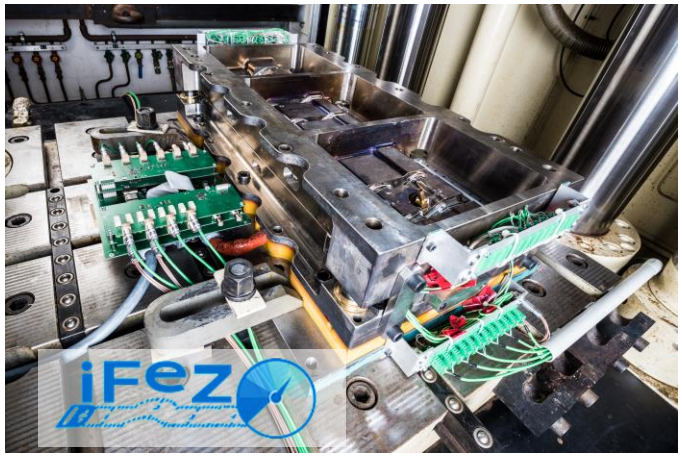
Digital Infusion Center

- Contributing Projects: iFeZ (German LUFO)

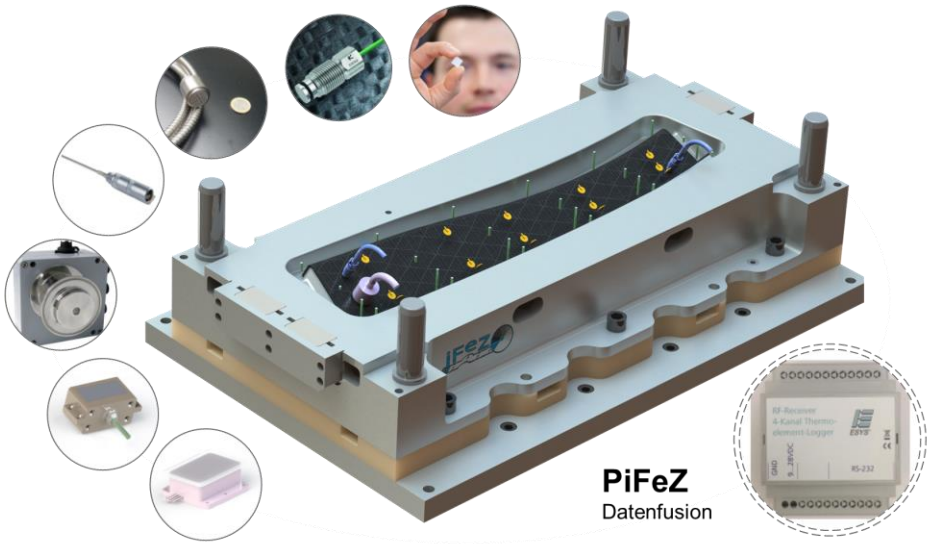
  RTM Fuselage Frame Segment

  – Fully functional multi sensor network
  – Wireless data transmission
  – Sensor sensitivity and robustness
  – Constantly updated flow simulation



Sensors:
- US-Sensors
- Pressure Sensors
- Dielectric Sensors
- Thermocouples
- Eddy Current Sensors

Data Fusion: Raspberry Pi based



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Digital Infusion Center

- **The Digital Infusion Center**
  - Hot-swappable double container (continuous infusion option)
  - Powerful, energy efficient and highly responsive microwave resin heating
  - Sensor controlled automatic mode and fully manual, experimental mode
  - Full network integration / interface for tooling sensors
  - Part of a fully controllable environment (press, oven and autoclave)

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Suction Rib Results

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Suction Rib Results

- **Trial 1**, Pre-Trial (Sicumed RT resin)
  - Out of autoclave approach
  - Reduced laminate thickness
  - Room temperature curing resin
  - Test of digital infusion center
  - → Various problems

Trial 1

Trial 2

- **Trial 2**, Verification-Test (Hexcel RTM 6)
  - 6 bar autoclave infusion process
  - Programmed automatic infusion
  - 30 min infusion (as simulated)
  - Ca. 290 min total cycle time
  - → TRL 3 verification successful

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Suction Rib Results

- **Trial 1, Out Of Autoclave (ambient pressure) Infusion Log**
  - → Start with infusion center in automatic mode
  - – Insufficient resin flow (deviation from simulation)
  - – **Updated simulation shows that filling is impossible**
  - → Infusion center switched to manual mode
  - → Applying overcritical (>1 bar) infusion pressure
  - – Flow increases but resin slowly inflates bagging
  - – Exothermal resin temperature increase in container
  - → Infusion terminated after enough resin has been forced into the vacuum bag
  - → Vertical positioning of tooling to utilise gravity
  - – Remaining dry spot only in access door cut out

Creative measures saved demonstrator after more than 5 hours of infusion.
Error tracing: Partially blocked infusion port caused the resin flow problem.

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Outlook

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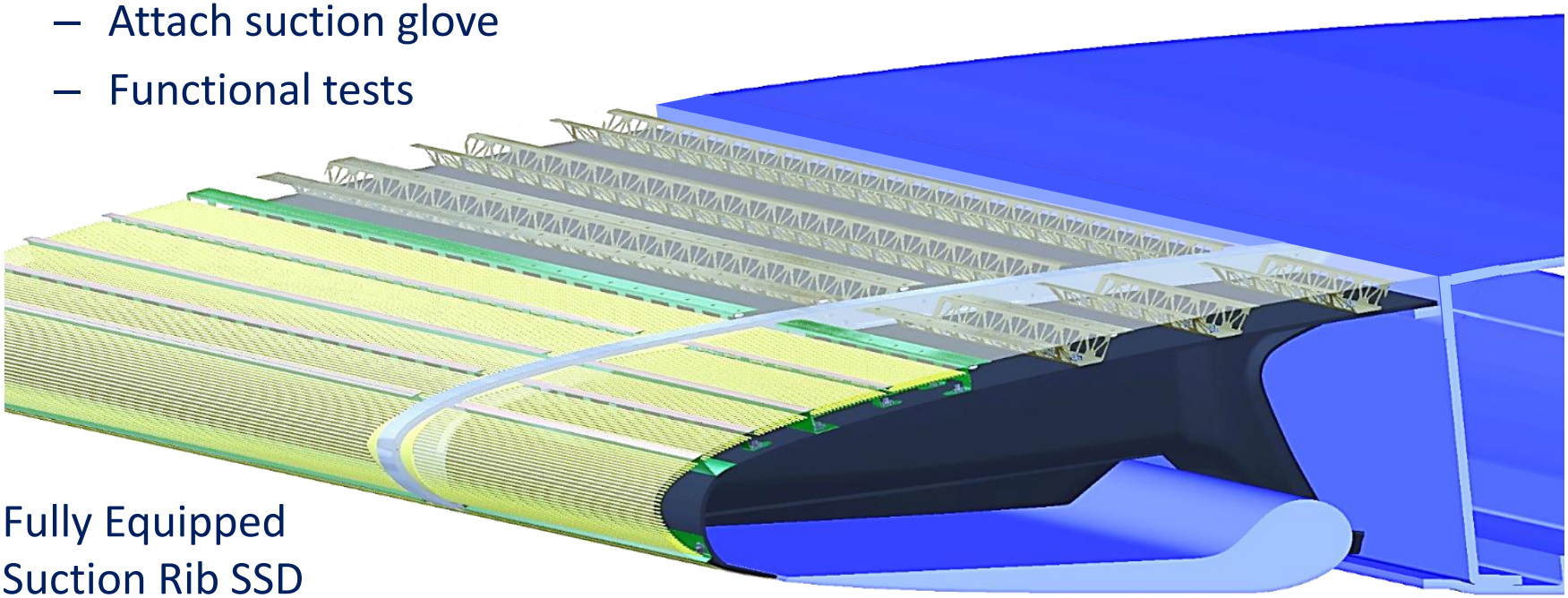
Outlook

- **Suction Rib SSD**
  - Build and assemble remaining CFRP components
  - Install inverter and compressor
  - Install inductive de-/anti-icing dummy
  - Attach suction glove
  - Functional tests



Fully Equipped
Suction Rib SSD

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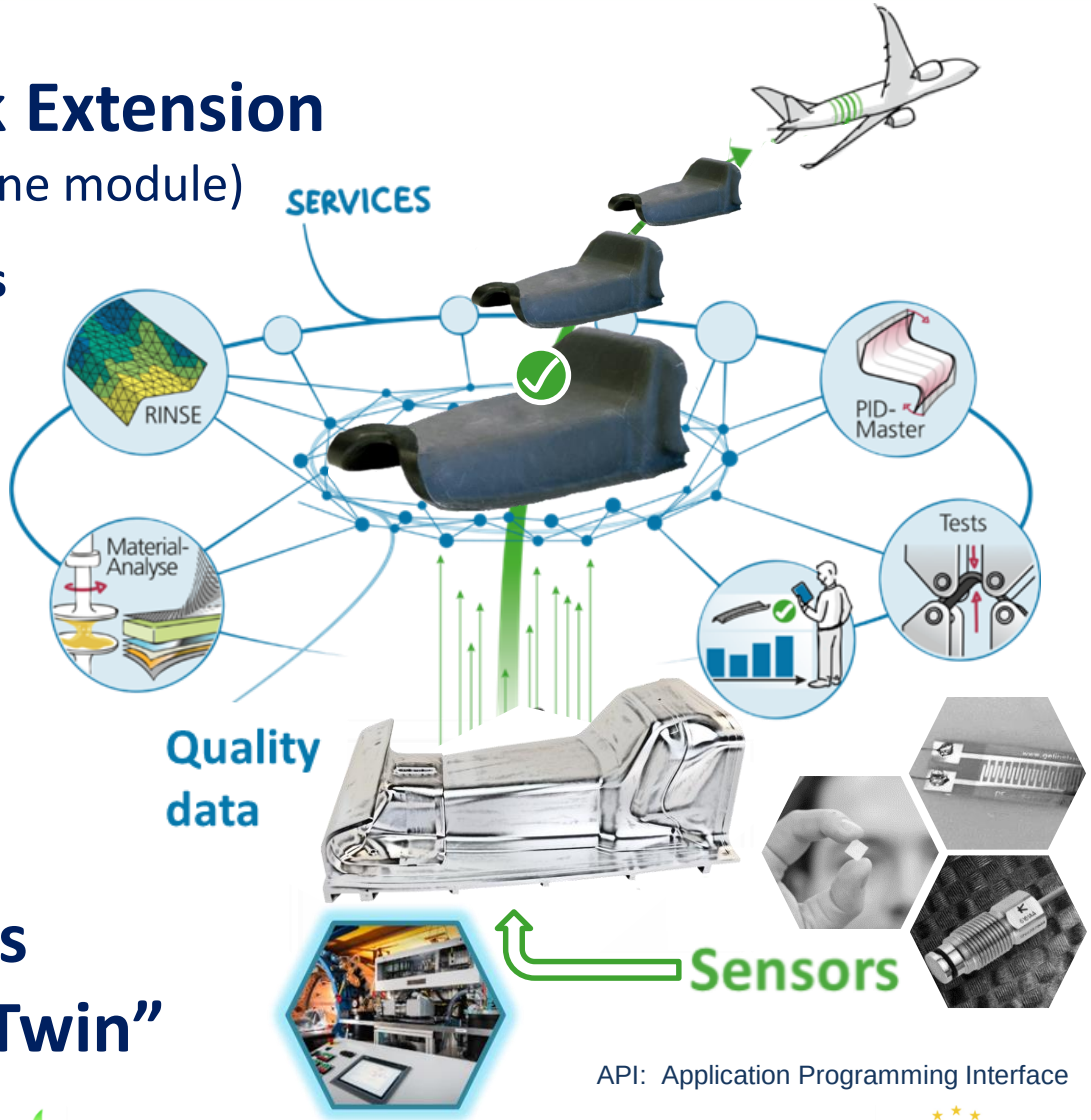
Outlook

- **API Based Network Extension**
  (Digital Infusion Centre is one module)
  - **Equipment Capabilities**
  - **Process Sensors**
  - **Software Services**

Continuously Optimised Production Process logged in "Digital Twin"



API: Application Programming Interface

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