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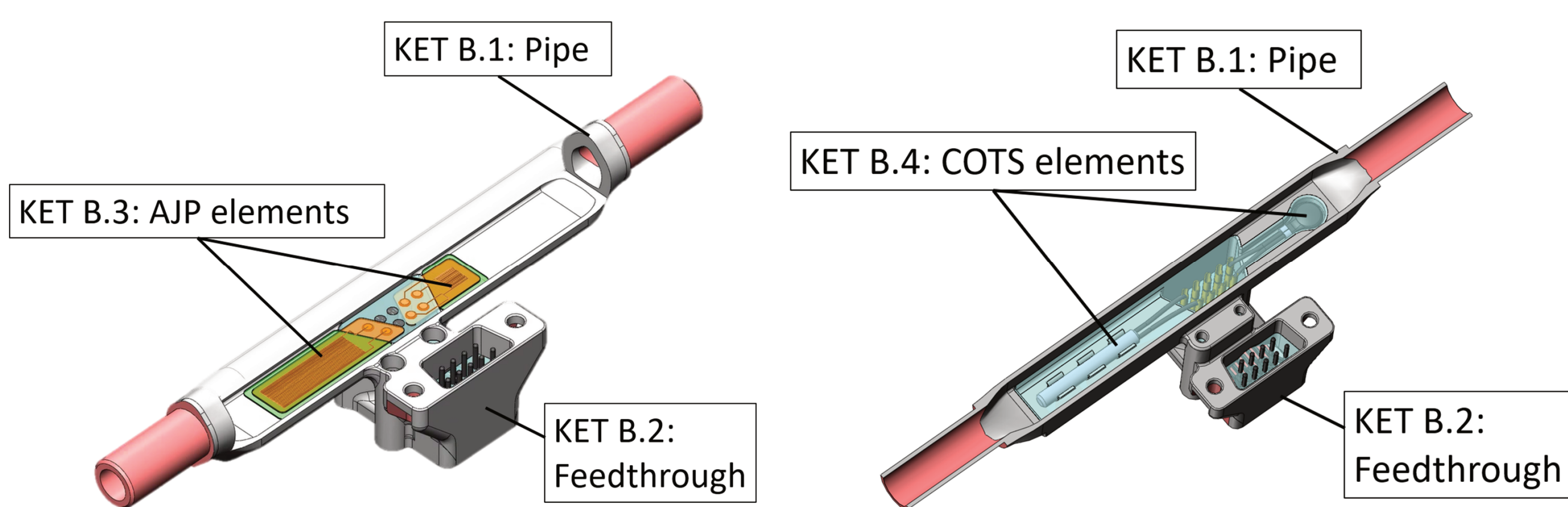
## Introduction

The Advanced Heat Exchange Devices (AHEAD) project utilises Additive Manufacturing (AM) technology to develop metal 3D printed pipes including temperature sensors, heaters directly integrated into the pipe. Thanks to a patented design [1] and an initial study during the project SWaP [2], AHEAD is targeting to improve and overcome the limitations of current methods of monitoring fluid properties on thermal management systems.

## Key Enabling Technology (KET) Bricks

The first phase of the project concentrates on designing, manufacturing and testing the KET bricks that are illustrated in Fig. 1. and those are:

1. AM pipe segments
2. AM electrical feedthrough and connector
3. Aerosol Jet Printed (AJP) temperature sensor and heater integration
4. Commercial of the shelf (COTS) temperature sensor integration

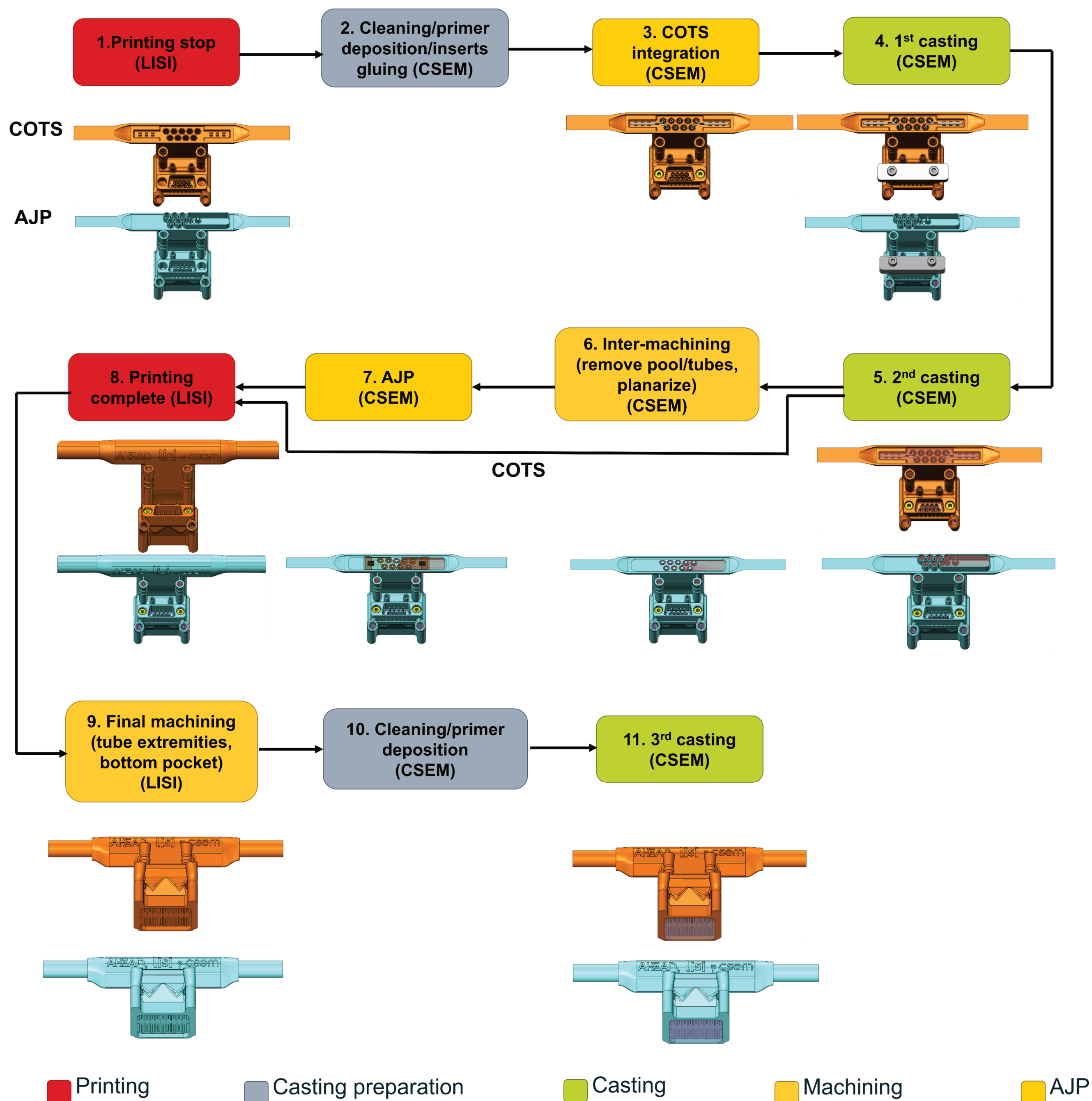


**Figure 1.** Architecture of the two use-cases in terms of Key Enabling Technology Bricks, AJP version (right), COTS version (left)

In order to incorporate the elements into the pipe:

- AM LPBF (Laser Powder Bed Fusion) process is being **stopped**
- The build plate is moved for:
  - the **casting** of the feedthrough
  - the **integration** of the elements
- The build plate is being placed back to the printer to:
  - to **resume** the LPBF process
  - machine the mechanical interface

In between all these steps, proper cleaning and inspection is being performed.



**Figure 2.** The eleven stages process of integrating COTS and AJP sensors inside the pipe, produced by stop and resume AM

[1] H. Saudan, L. Kiener. Method for manufacturing a 3D electromechanical component having at least one embedded electrical conductor. European patent 3740382 B1, 2022-05-25  
[2] C. Manoli, N.R. Hendricks, J. Noël, P. Petagna, and S. Lani. (2021). Smart Wall Pipes and ducts (SWaP). Public deliverable for the ATTRACT Final Conference

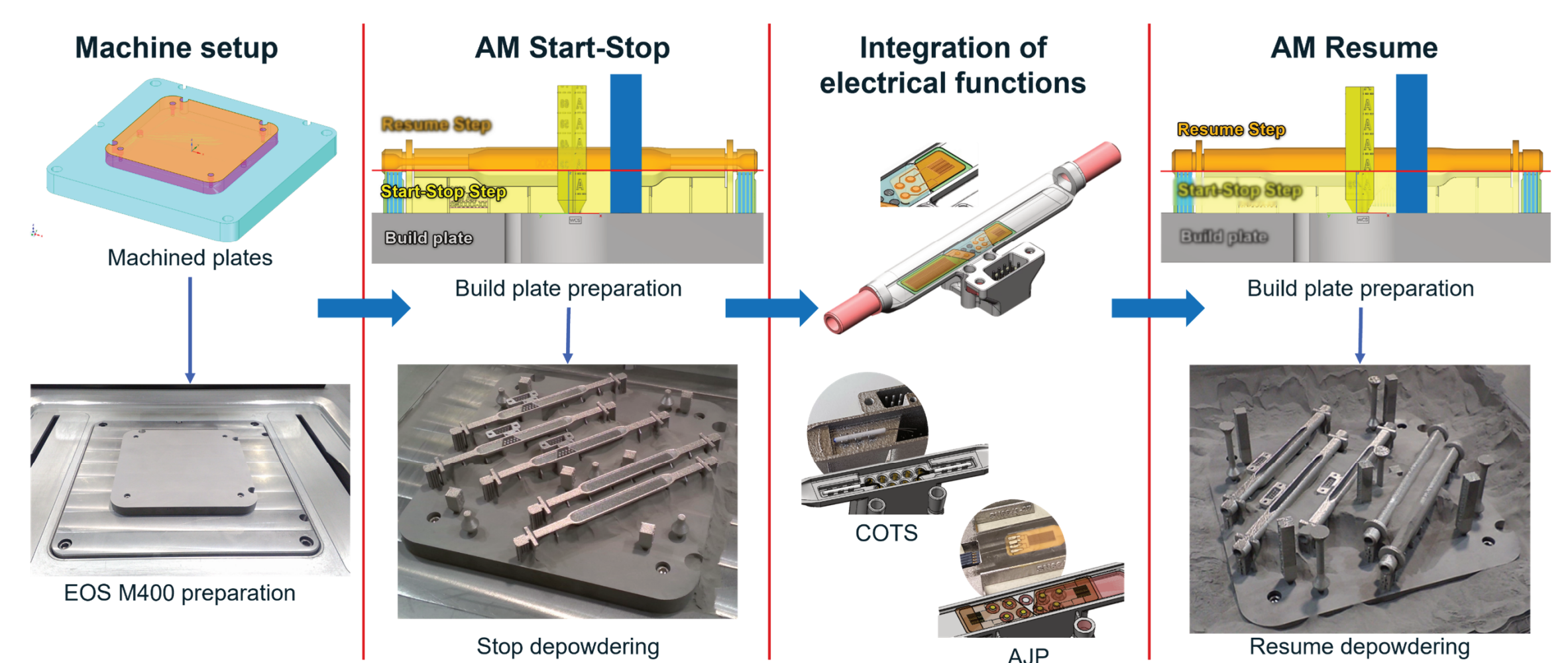
## AM Start, Stop and Resume

AM **Start – Stop** challenges:

- Precise **build plate** setup and minimized distortion
- **Common reference** between CAD and the machine
- Anticipation of **AJP needs**
  - build plate size, best stop height, mechanical interfaces
- Respect **cleanliness** specification

AM **Resume** challenges:

- Precise **build plate** setup after the integration of sensors
- Clean and clear **layer** to start
- Monitoring the temperature in **AJP area**
- Geometrical and material **quality after resume**

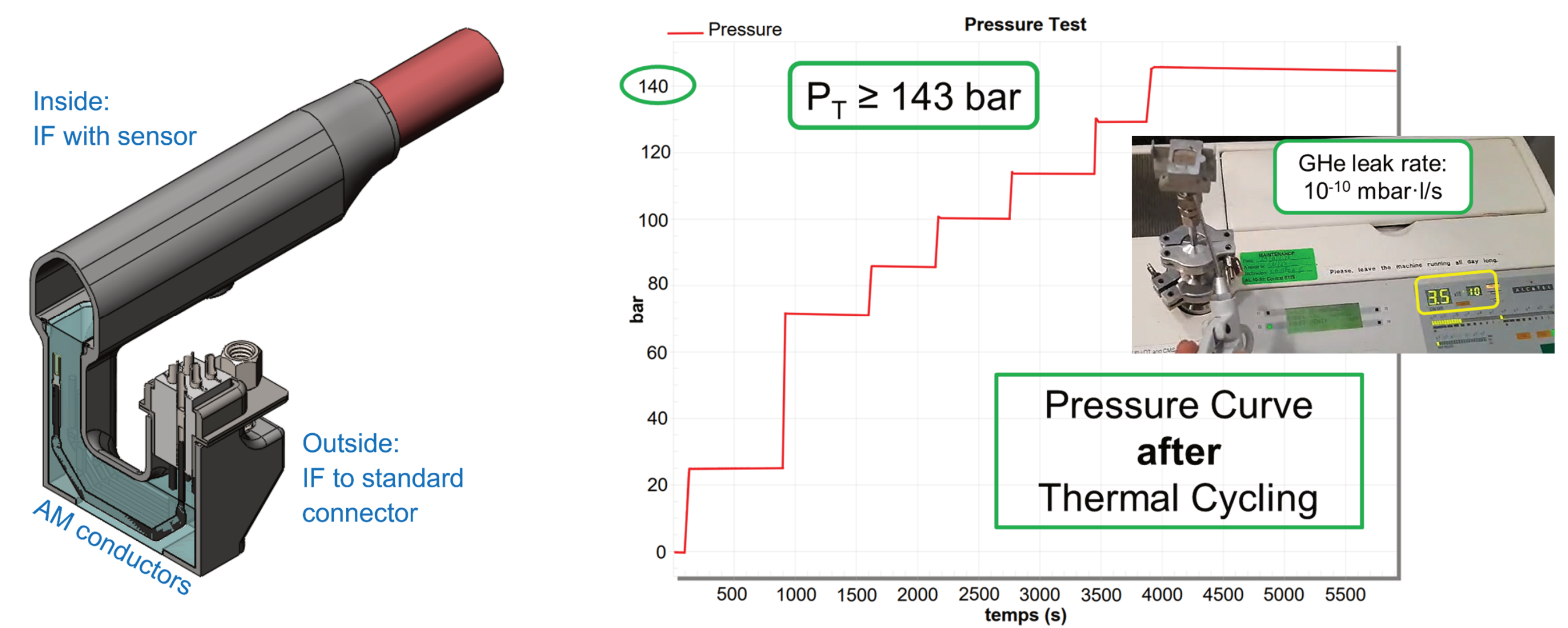


**Figure 3.** Illustration of the AM Start – Stop – Resume manufacturing process

## AM electrical connector feedthrough

Resin **specifications & casting** challenges:

- **Low viscosity** for easy casting
- **CTE matching** between resin and stainless steel
- Resin **sufficient adhesion** to stainless steel
- Good **chemical compatibility** with the refrigerant (CO<sub>2</sub>)
- **Leak tight** and resistant to the operational **pressure and temperature**



**Figure 4.** Casted feedthrough (left) and leak, thermal and pressure test results (right)

## AJP and COTS sensors

Capability to **develop**:

- RTDs with similar properties to **Pt100/1000**
- **Heaters** to locally heat the fluid
- Multilayers of **dissimilar materials**
- Metals, semiconductors, insulators, epoxies, organic & biological materials

Capability to **integrate**:

- **Passive/active elements**:
  - Sensors
  - Heaters
  - Light sources
  - Combinations of the above

