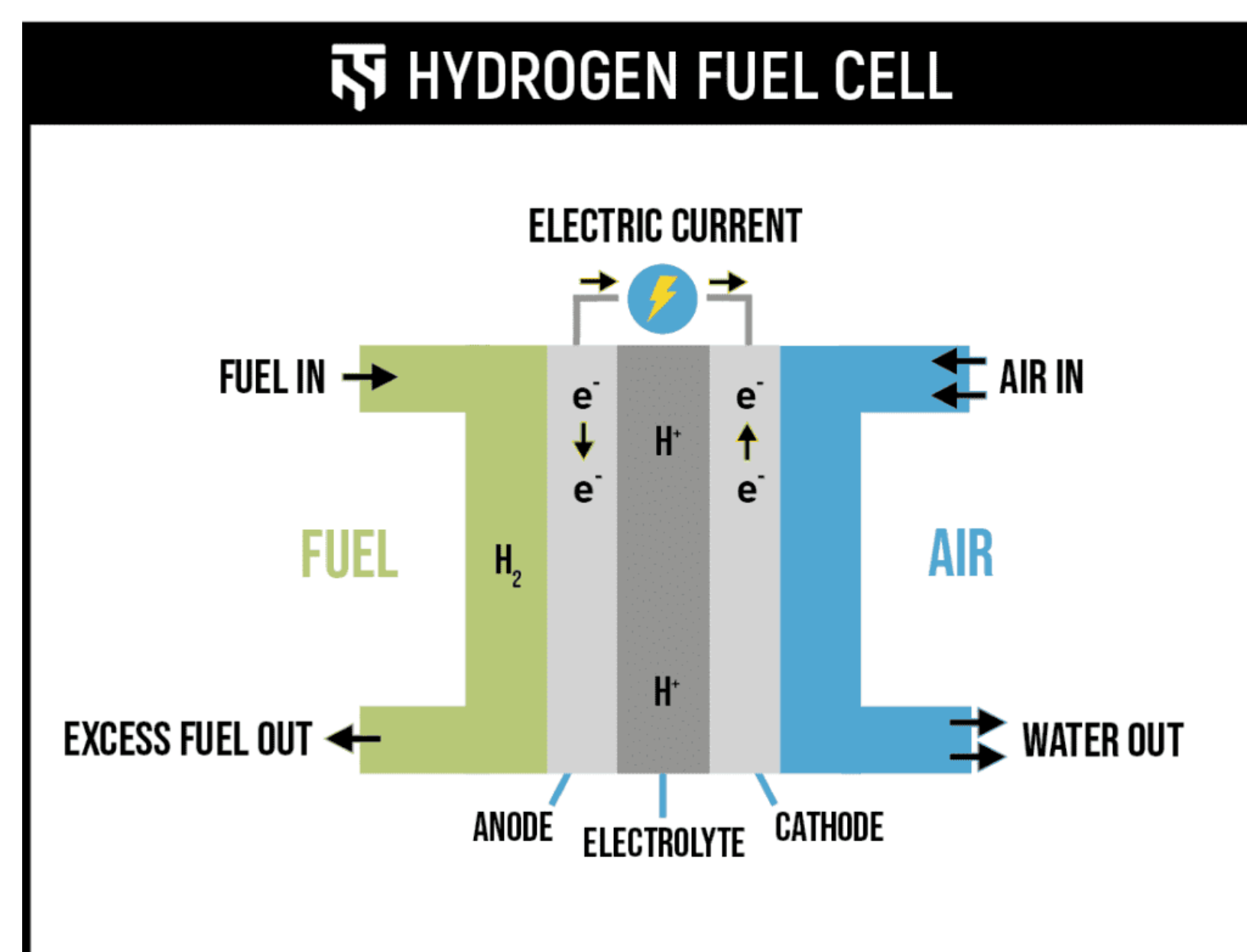


Motivation

- The world is racing to achieve **Net Zero greenhouse gas emissions by 2050**
- Hydrogen Fuel Cells offer a **clean energy alternative** to fossil fuels
- A fuel cell test rig will enable Woodward and CU to explore **components, systems integration, and controls technology**

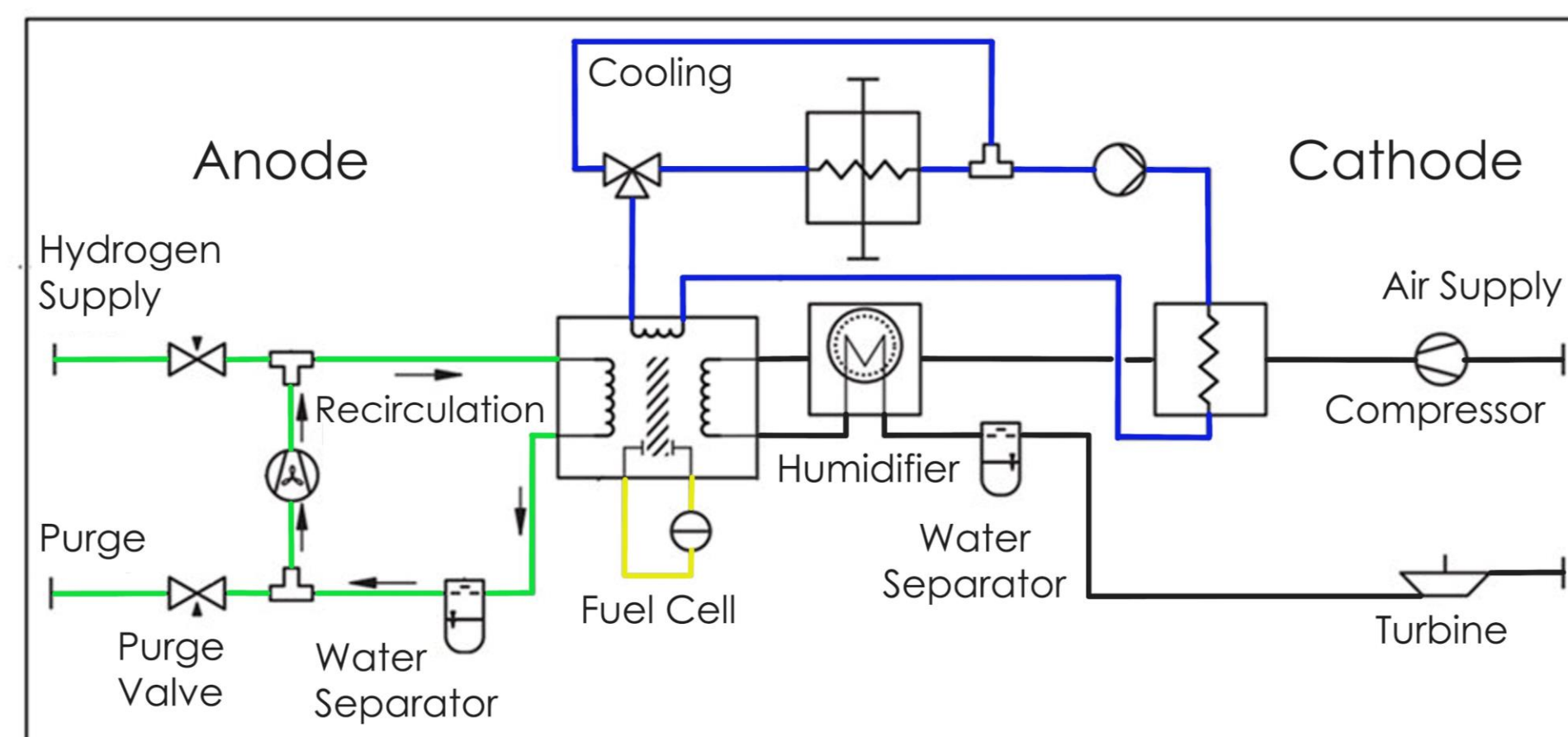
What is a Fuel Cell?

- Open system which acts **like a battery** without needing to be charged
- Water and heat** are the only byproducts



What is Balance-of-Plant?

- Balance-of-Plant designates all the **auxiliary systems** (everything except fuel cell stack)



Objective

Build a 16 kW FC test rig with **hydrogen, air, water, and power management** systems

Specifications

- Dissipate **20kW** heat
- Operate FC from **10-100%** load level
- Remote **monitoring and control**
- Use **modular, oil-free** components
- Run time of **4-6 hours**
- Measure **pressure (P), temperature (T), humidity (H), and flow rate ($\dot{m}$)**
- Fully **enclosed, ventilated** with easy access

Hydrogen Loop

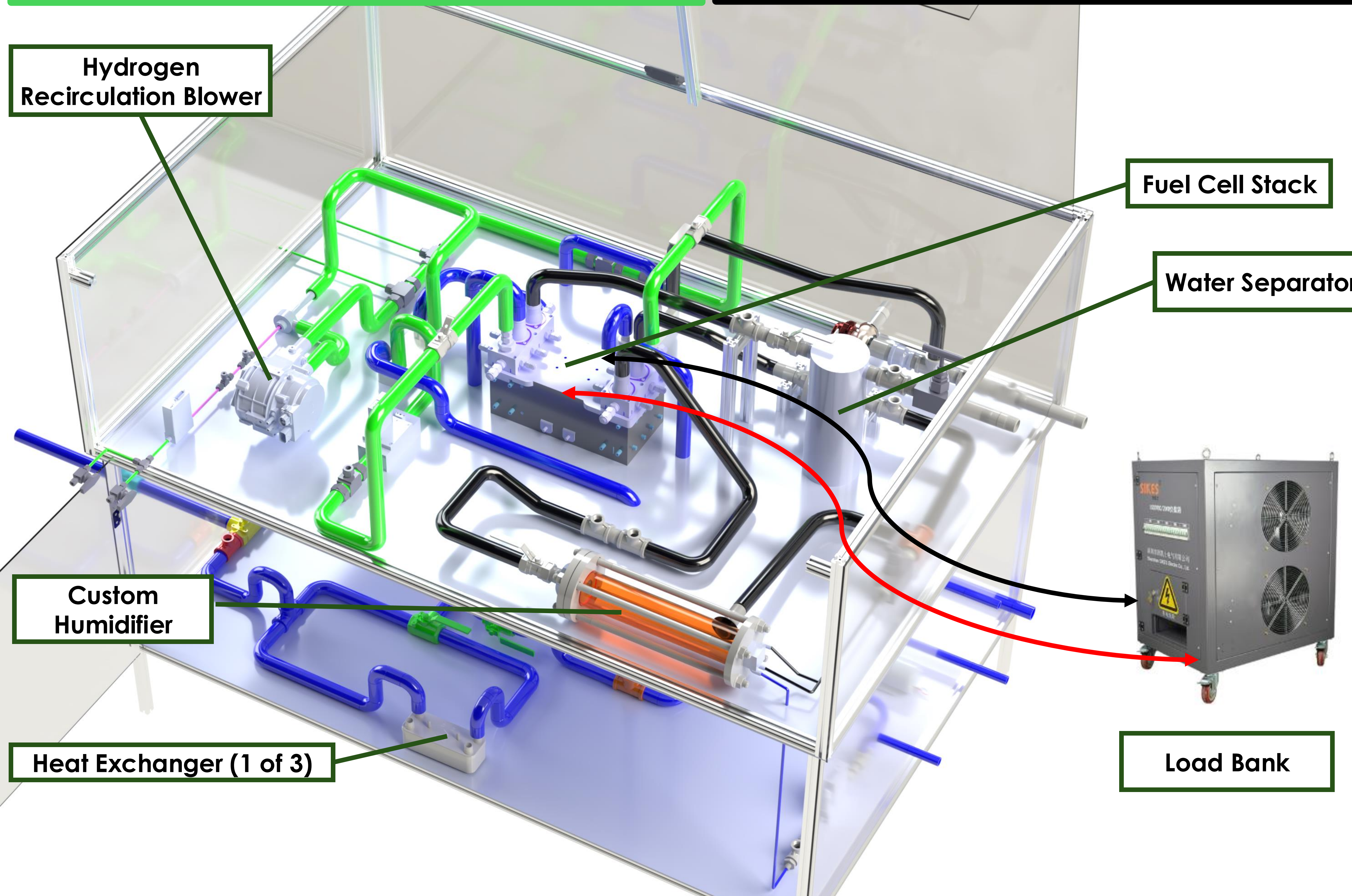
Supplies hydrogen to **anode**, which must maintain correct **P, T, H, and $\dot{m}$**

- Ejector mixes **high pressure hydrogen** to **low pressure loop**
- Recirculation Blower **circulates** the **residual hydrogen**

Air Loop

Supplies air to **cathode**, which must maintain correct **P, T, H, and $\dot{m}$**

- Compressor **increases pressure and temperature**
- Waste gate valve diverts air to **regulate flow**
- Custom humidifier precisely controls **water injection**



Cooling Loop

Dissipates up to **20 kW of heat** from FC stack, which must maintain correct **P, T and $\dot{m}$**

- Maintains** coolant temperature
- Cools** air and **heats** hydrogen

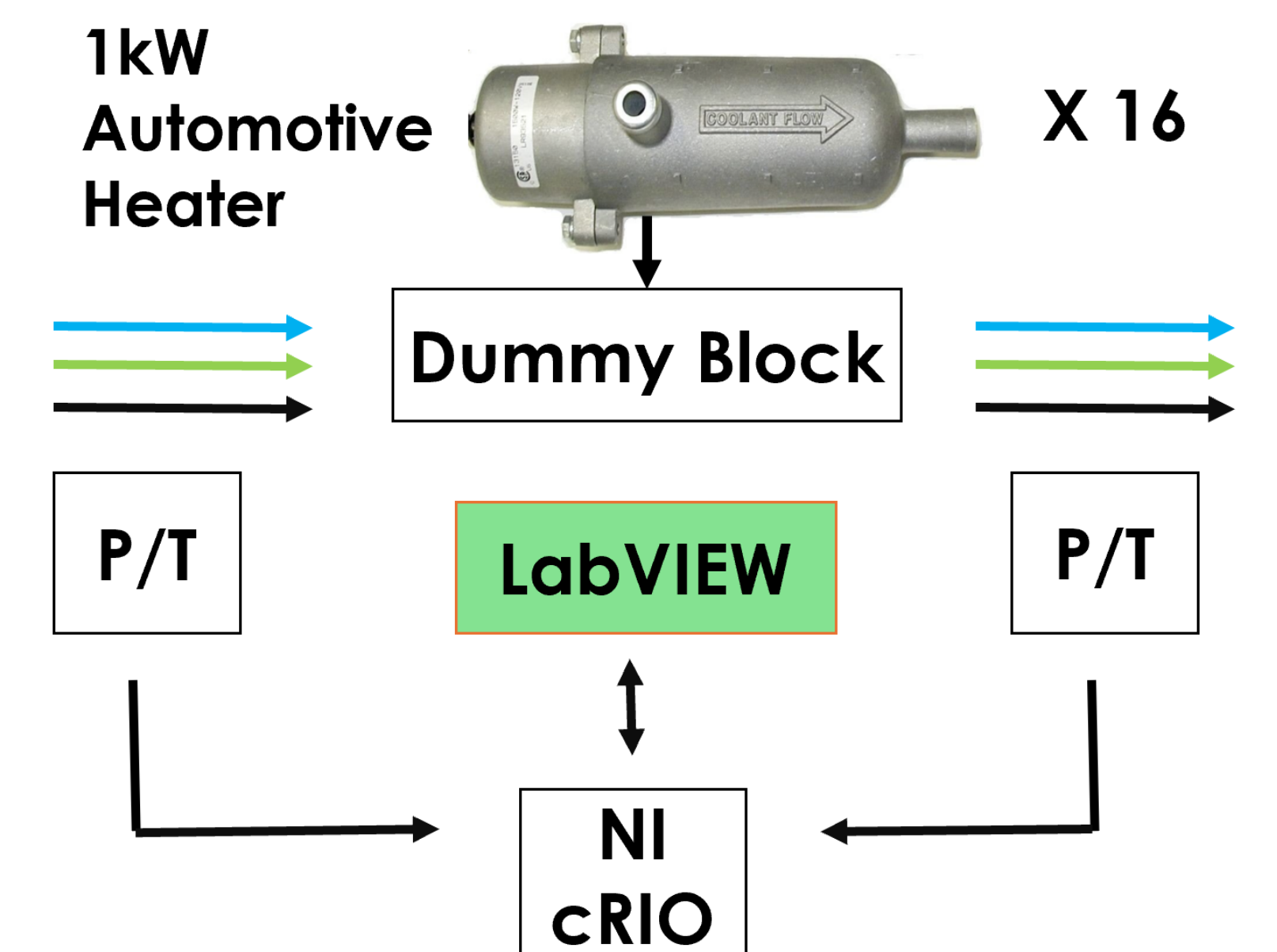
Control System

The "brain" of the rig, reads sensor data, controls the actuators, valves, pumps and compressor

- Real-Time remote** monitoring & **data logging**
- Triggering **valve closures, power cuts**

Test Plan

- Individual Loop** Testing
- Maintain **200mbar ΔP** between anode and cathode
- Dummy block to **simulate** FC stack
 - Provide **16 kW** of heat to cooling loop
- Circulate air and hydrogen



Challenges

Programmatic

- Expensive** custom components
- Budget** constraints
- Multiple** stakeholders

Technical

- Large flow variations
- Varying load levels
- Custom humidification of air
- Hydrogen usage and safety
- Oil-free components
- Strict pressure control

Over 400 components

43 sensor measurements

19 electric components

Project Timeline

