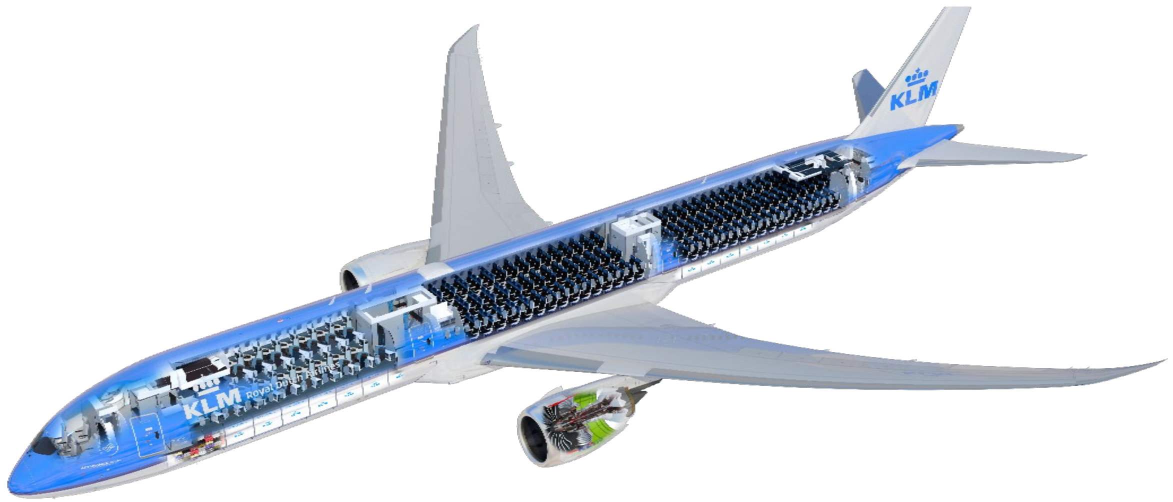

KLM

An AI-based Digital Twin Case Study in the MRO Sector

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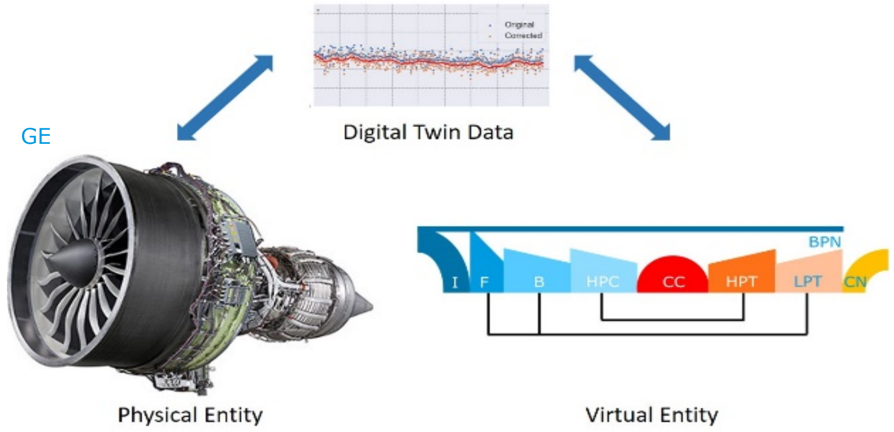
AI for MRO in Aviation: Current landscape

- Starting point: Availability of aircraft
- AI has the potential to identify patterns in technical data and records, and streamline maintenance, increase availability and reduce costs and incidents
- Aircraft operators are looking to understanding the behavior of their assets over a long period of time
- Data availability a major bottleneck in the process
- Conflict in data sharing between OEMs, lessors, operators and MRO providers. All rely on operators for sufficient amounts of data

Digital Twins

- No unique definition of a DT in literature



- A combination of multiple technologies, embedded in three components:
  - Physical entities in the physical world
  - Virtual models in the virtual world
  - Connected data that tie the two entities together

- In the present study, the employed DT model is considered as a detailed digital representation of the physical components of an aircraft system with the use of relevant data from various sources

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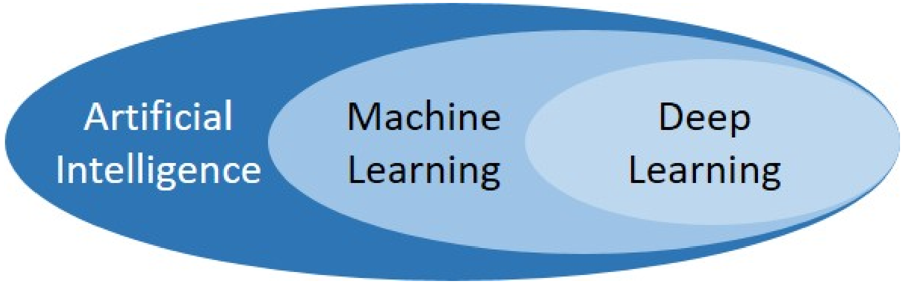
Challenges

- Physical sensors designed to enable control of on-board systems
  - Environmental Control System (ECS), the Power Electronics Cooling System (PECS) and Engines equipped with the necessary types of sensors to maintain a stable function
  - The concept of prognostics and predictive maintenance are relatively new
  - Fewer sensors installed than needed for data analytics

AI and MRO

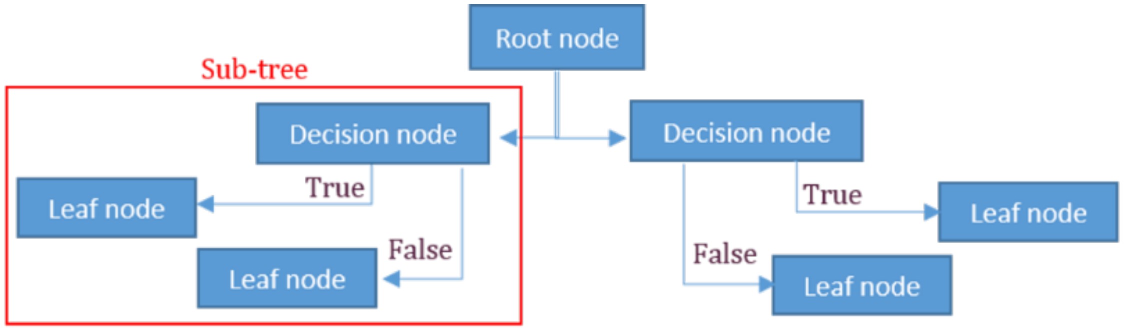
- Focus on Machine Learning:
  - Random Forest derives from conventional Decision and Fault Trees, have a high relevance with the standard practices and engineering logic used in fault detection
  - AI needs to be explainable for safety considerations -other methods such as Deep Learning are not transparent or explainable enough
  - Industry-wide efforts to develop the standards for certification of AI

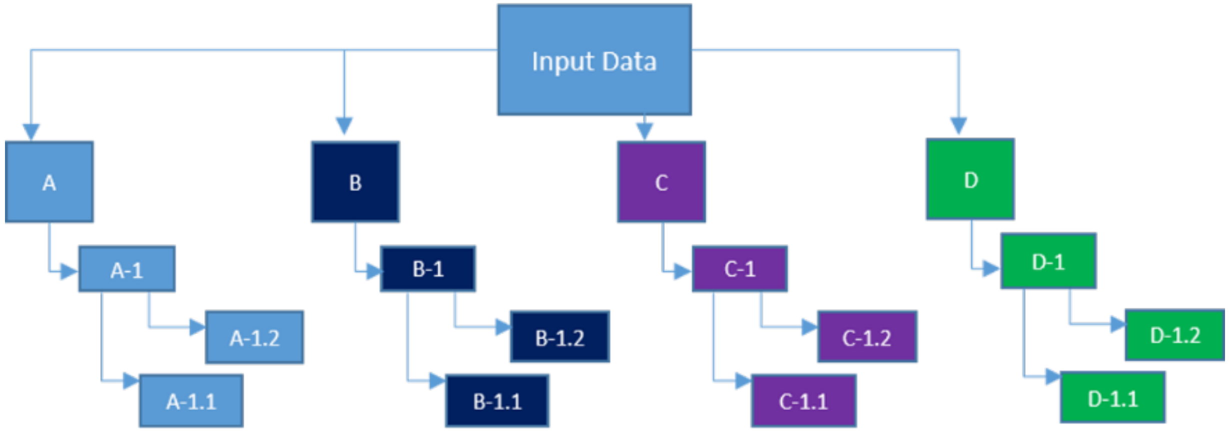


Why PECS (Power Electronics Cooling System)?

- The main objective is to develop a framework that determines the optimal physical location and type of sensors in an ideal PECS of a modern airliner
- Failures in PECS have a high possibility of causing an Aircraft on Ground (AOG)
- Installation of additional sensors would increase health monitoring capabilities
- Place sensors which can feed with input parameters the AI-based DT
- Failure rates of components are not considered
- The development of the model itself will be addressed in future work

Decision Tree and Random Forest





Proposed Model

- The employed model is a detailed digital representation of the PECS
- With sensor data and historical maintenance data, the DT can describe, optimize and predict the performance of the system
- The objective is to provide accurate predictions by capturing a range of degradation and failure mechanisms
- The Random Forest is capable of detecting outliers, associating them with known or unknown issues and failure modes
- A physics-based model can be used to simulate the operational spectrum, providing additional training data points for the data-driven method

Modelling

- Three different concepts were considered:
  - General Design: Overall system sensor layout
  - Detailed Design: Detailed sensor layout of the components
  - Combined Design: A detailed design for the whole PECS system

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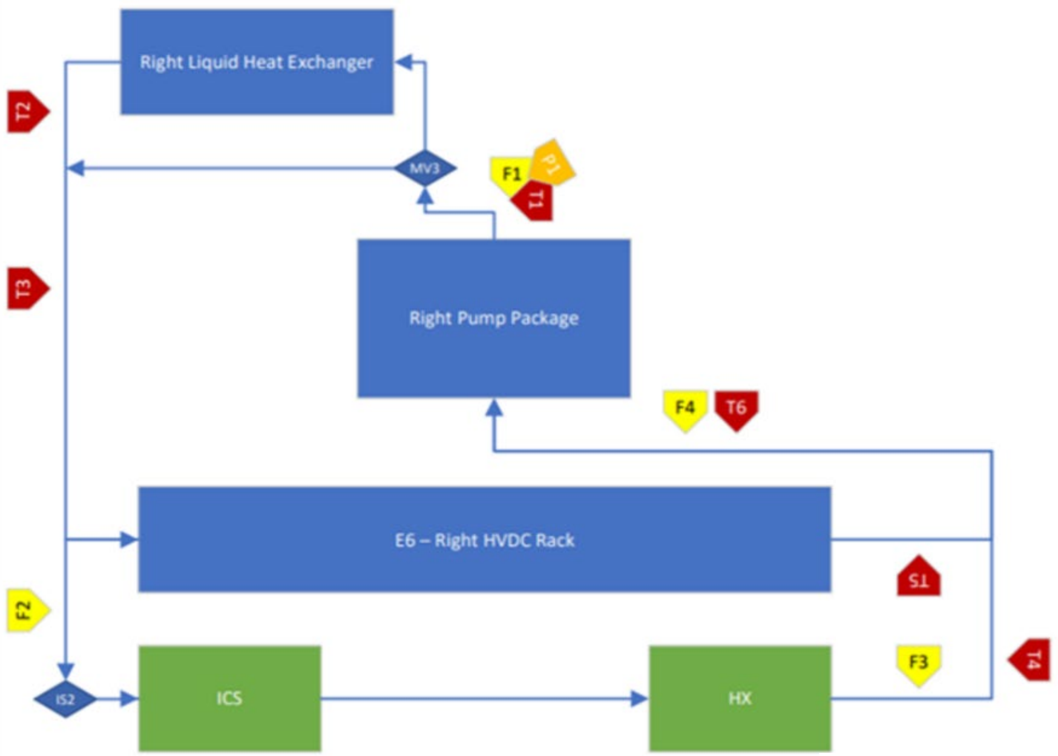
General Design

- Macroscopic, over-engineered perspective
- Ideal approach, where all systems parameters are measured
- Three different parameters need to be known in each station:
  - Mass flow rate
  - Static temperature
  - Static pressure



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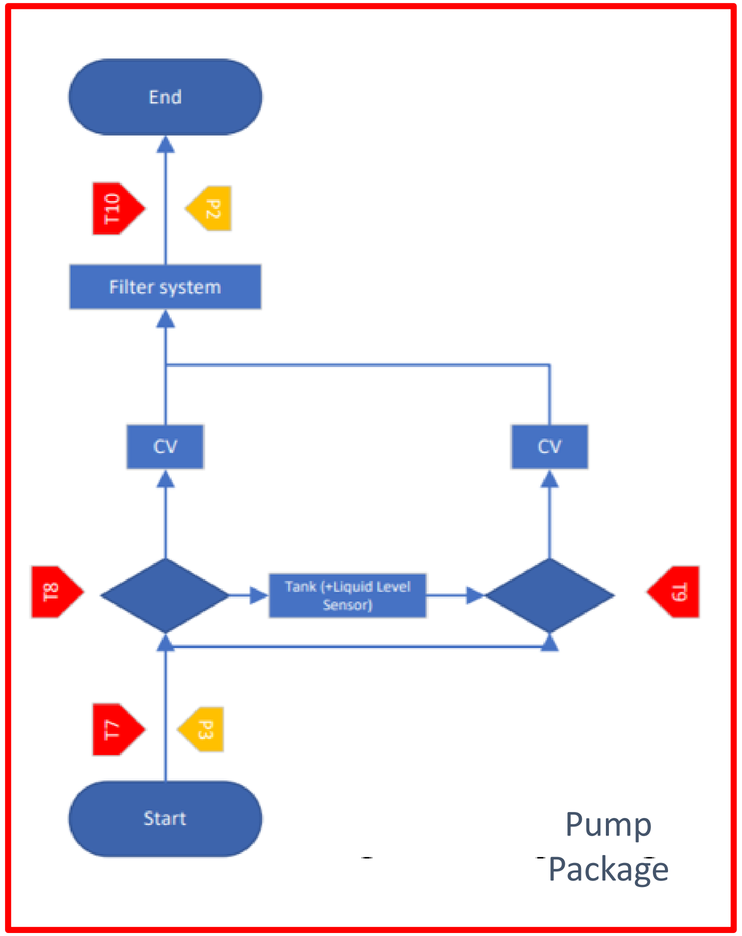
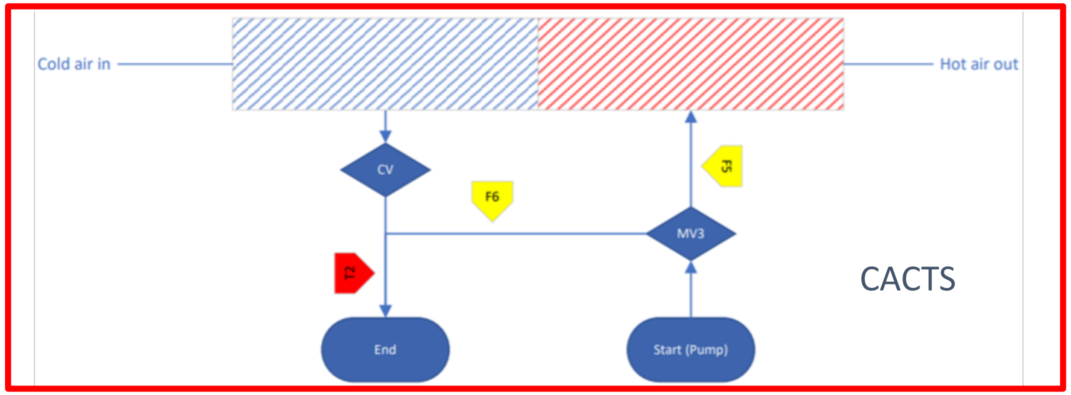
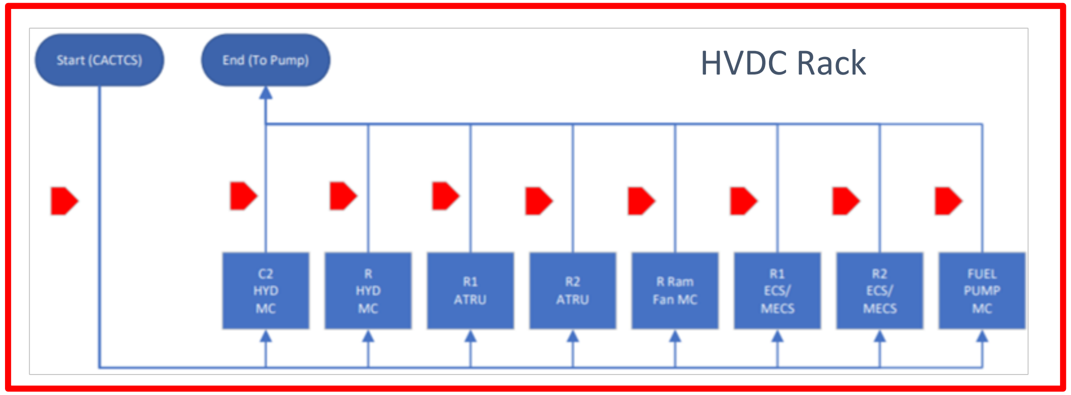
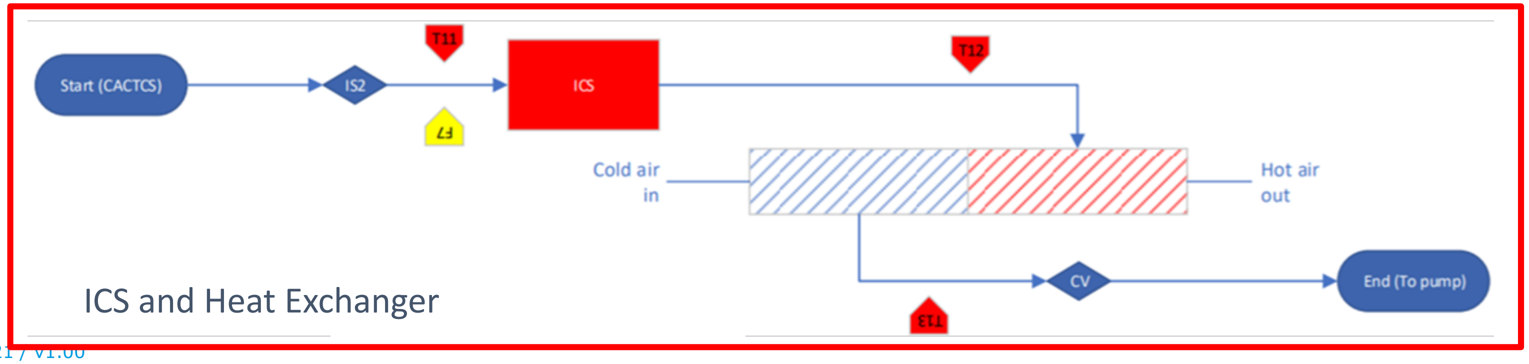
Detailed Component Design



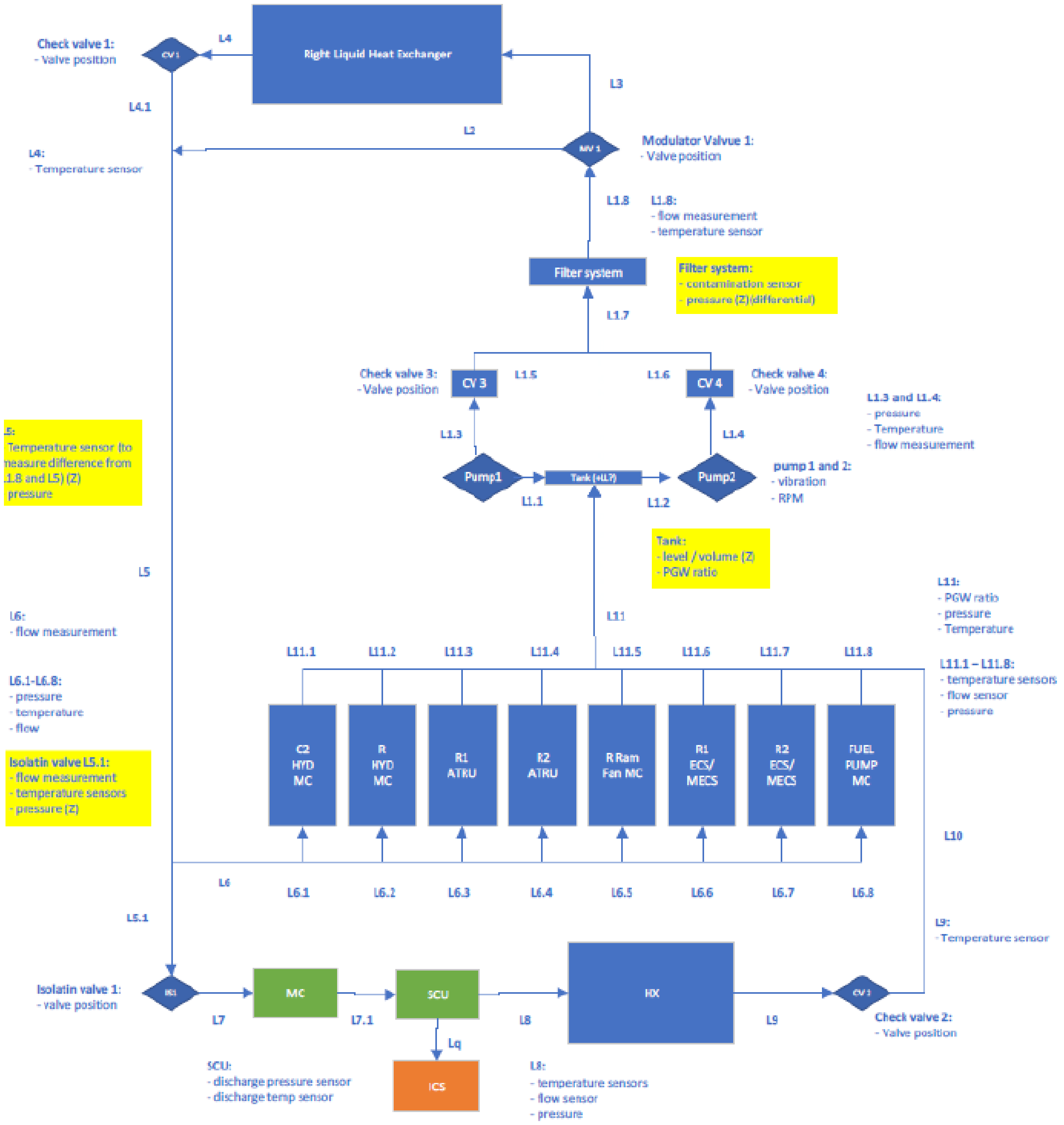






Combined Design

- Combined design derives from General and Detailed Component Design
- Branches with sequential number (Lx.x)
- Z indicates a pre-existing sensor



Conclusions

- Redesign of PECS instrumentation for AI-based Digital Twins
- Sensors now not only for control but for Diagnostics, Prognostics and the calculation of the Remaining Useful Life
- Demonstration of ideal instrumentation layouts
- Output data processing:
  - Training an AI model, such as a Random Forest
  - Number of sensors can identify the type and the location of a fault
- Physics-based model for verification for the data-driven model:
  - Anomalies can be signaled and compared against normal operation
  - Results can be used to train the AI model

Thank you

- **Q Questions?**

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