SMARTFUEL
THIRD GENERATION DIGITAL LIQUID MANAGEMENT SYSTEM

Hans Dietrich Schnell
AUTOFLUG GmbH
Rellingen, Germany

1. Abstract

SmartFuel is a research and technological development project within the fifth framework programme of the European Commission.

SmartFuel is developing a strategic concept for a fully digital control system, using **distributed intelligence**, for the management of airborne fluidic systems like fuel, water and hydraulic oil on board of aircraft.

Main objective of ***SmartFuel*** is to replace the current concept of **centralised computers** controlling simple components by **bus interfaced all smart components** being supervised by a less complex **monitoring computer.**

SmartFuel will significantly reduce the aircraft wiring harness complexity, which results in **better electromagnetic** compatibility **and weight savings**. The distributed intelligence will **improve** the **operational performance** with rapid response times to system state alterations and user operation requests.
The project ***SmartFuel*** is co-ordinated by Autoflug GmbH. You can contact the consortium at its homepage http://www.smartfuel.aero/.

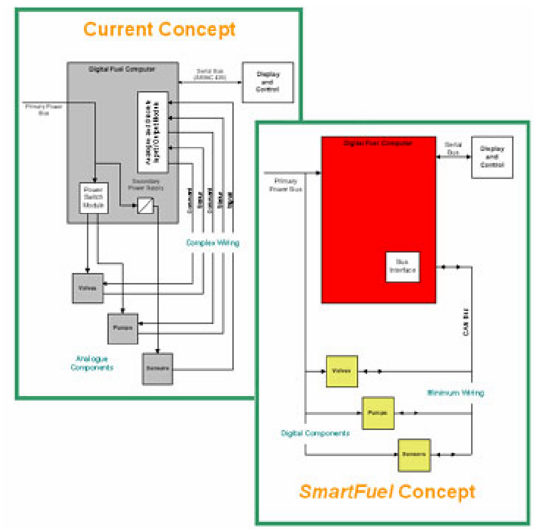


Fig. 1 ***SmartFuel*** vs. Current Concept

2. The ***SmartFuel*** Consortium

Nine European companies and universities team within the ***SmartFuel*** Consortium:

- Airbus, United Kingdom

  Airbus provides the fixed wing system requirements and is involved in the numerical validation of the optimised balancing/transfer mode using a smart positional valve.

- ASG Weinheim, Germany

  ASG provides the common core CPU (hardware & software) for the smart components and is responsible for the positional valve.

- Autoflug, Germany

  AUTOFLUG will provide the monitoring computer and the smart fuel sensors.

- Eurocopter, Germany

  Eurocopter provides the rotary wing system requirements and will perform ***SmartFuel*** system validation with wet rig testing.

- Goodrich, France

  Goodrich manages the ***SmartFuel*** communication protocol definition and supports the smart valve and smart fuel pump provision.

- Secondo Mona, Italy

  Secondo Mona will provide smart fuel pumps to the project.

- Universidad de Alcala, Spain

  Universidad de Alacala supports the fuel computer software development and is involved with the numerical simulation and validation of the ***SmartFuel*** system.

- Universidad Complutense de Madrid, Spain

  Universidad Complutense supports the communication protocol specification and provides the numerical system validation environment.

- Brno University of Technology, Czech Republic

  Brno University of Technology works out the communication protocol under respect of system and aircraft safety requirements.

The EC Scientific Officer Dr. Marco Brusati, Italy supervises the project SmartFuel.

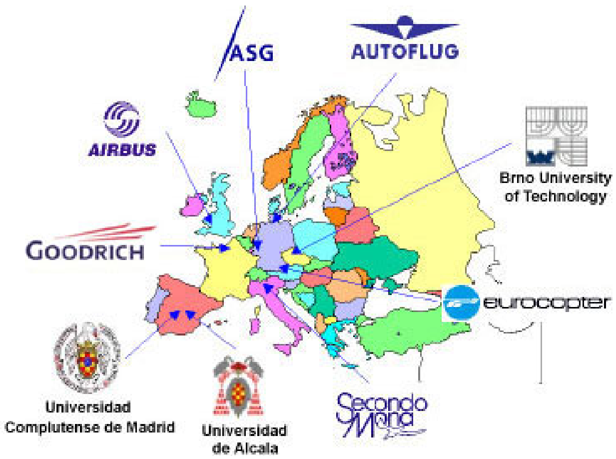


Fig. 2 The ***SmartFuel*** Consortium

3. Current Concept of Fuel Management

The central component of current fuel systems is the fuel computer.

All actions of system components like valves pumps and sensors are directly controlled and monitored by the fuel computer:

- Power switching
- Command triggering
- State and signal monitoring

This centralised architecture without smartness of the sub-components results in complex wiring and demands very high reliability requirements on the central fuel computer.

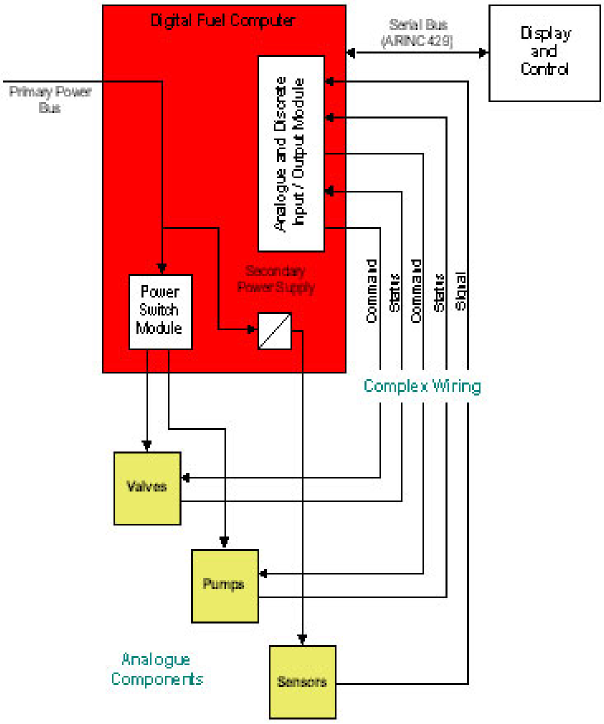


Fig. 3 Current Concept of Fuel Management

Fig. 3 depicts a conventional fuel management system with a digital fuel computer.

The disadvantages of this configuration are obviously: only the fuel computer has an interface with the A/C primary power bus. Via a power switch module the fuel computer controls the power components, pumps and valves, according to the management tasks.

The fuel computer via a huge number of discrete input signals monitors the actual condition or position of the power components. In addition the fuel computer commands some of the power components via discrete output signals.

Sensors of fuel management systems usually are not connected to the primary power bus of the A/C. The fuel computer provides the sensors with dedicated secondary power conditioned internally. Conventional fuel computers are then additionally fitted with special interfaces to process discrete, analogue or frequency-modulated output signals of the sensors.

4. ***SmartFuel*** Concept

The benefits of a digital system with smart components are:

- Increased reliability and safety due to redundancy and smart components
- Significant simplification over existing analogue fuel control systems
- Reduction by 50% in cabling and thus its resulting mass and installation time
- Improved system maintainability

The ***SmartFuel*** system concept will be simulated and tested on a fuel rig to demonstrate the results of the research project.

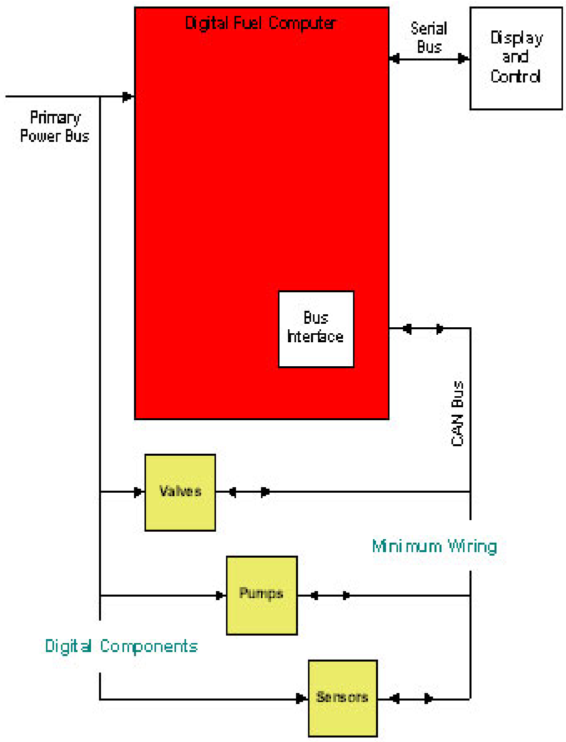


Fig. 4 ***SmartFuel*** Concept

Each component of the ***SmartFuel*** system is directly interfaced to the A/C primary power bus as shown in Fig. 4 above. Command, monitoring and measurement information is exchanged between the components via the CAN bus interface.

Using ***SmartFuel*** results in a significant reduction of the fuel management system's complexity.

The smartness of the components within ***SmartFuel*** allow to configure autonomous subsystems, e.g. a intelligent pump can be switched command by an intelligent low level sensor via the CAN bus when the tanks are empty without any interaction of the fuel computer or any other device of ***SmartFuel***.

5. Work Programme

The research project ***SmartFuel*** is run in the three phases:

- Definition
- Realisation
- Validation

The project started the 1st-Oct 2002. Its duration will be 36 month. The overall budget is approx. 4.2 M€ with EC funds of approx. 2.5 M€.

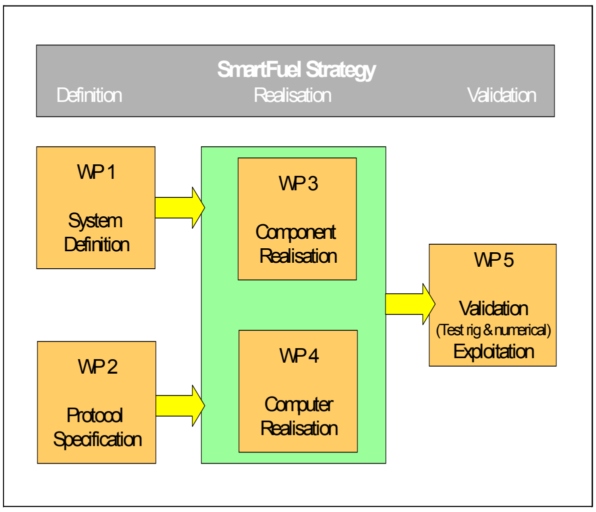


Fig. 5 Work Programme

6. Smart Components

Pumps, valves & sensors specified within this project will be smart and will all be fitted with an identical jointly developed **common core CPU** shown in Fig. 6.

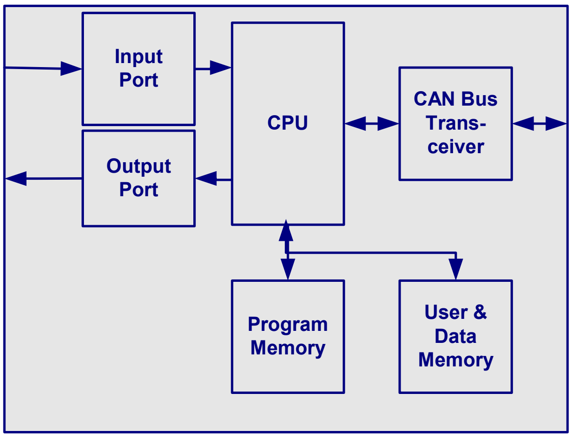


Fig. 6 Common Core CPU

Communication between the **smart components** themselves and the **fuel computer** will be via a **dual redundant CAN 2.0B bus.**

All **smart components** will make use of identical jointly developed **common software** as shown in Fig. 7 below.

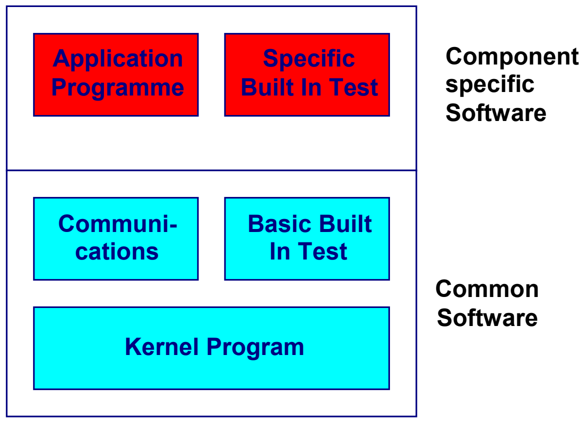


Fig. 7 Smart Components Software Architecture

The **smart component's** software will only differ in the component specific application program and specific built in test functions.

This will reduce the risk during software development and improve significantly the equipment formation time.

Use of **smart components** reduces the wiring harness complexity and improves the electromagnetic compatibility. Fig. 8 and Fig. 9 show the improvements in an AC pump interface.

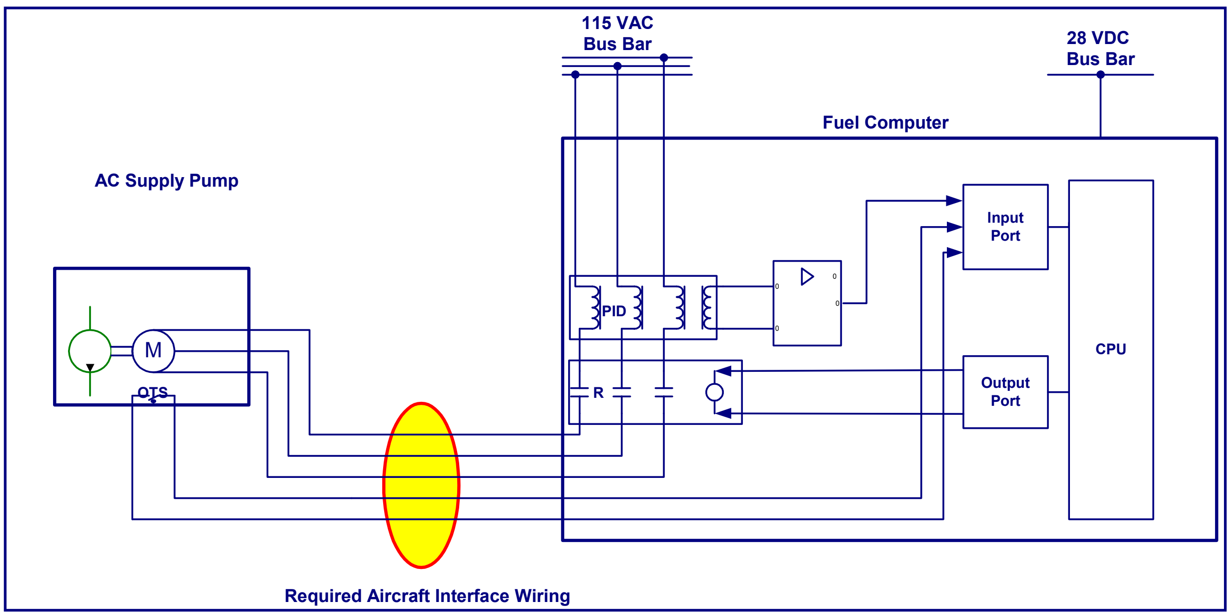


Fig 8. Conventional AC Supply Pump Interface

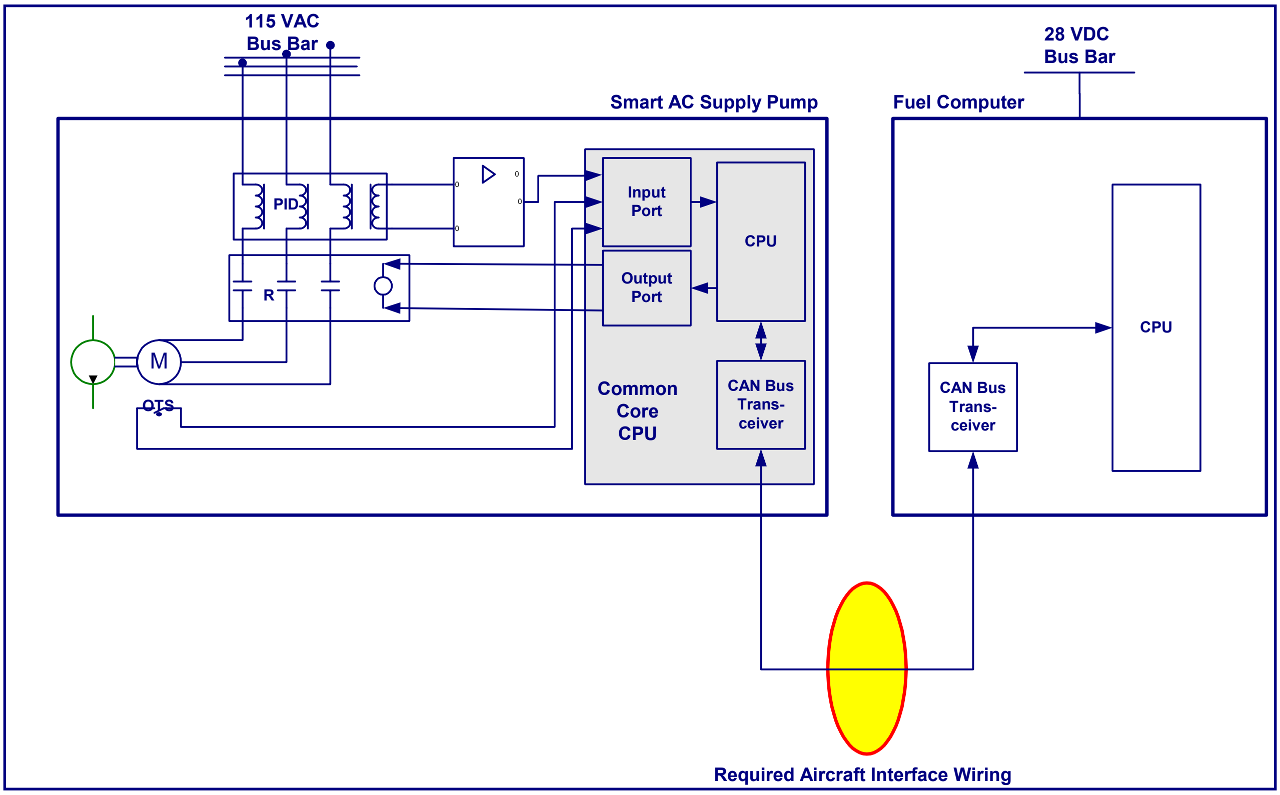


Fig. 9 Smart AC Supply Pump Interface

7. ***SmartFuel*** Operation Principle

All components of the ***SmartFuel*** system will have the **complete knowledge** of all operational modes, component states and their own mode membership **to enable** autonomous operation without central commanding.

The **Fuel Management Computer** acts as monitoring and interface device only. The information flow is shown in Fig. 10 below.

Fuel pumps and fuel valves will exchange digital control data with the other components via the bus interface. Fuel sensors in addition will send digitised analogue information, e.g. fuel height, fuel permittivity and fuel mass.

Each ***SmartFuel*** component will operate on the information contained in the **State Vector** and **Membership Vector**. The state vector will be identical for all smart components.

The state vector contains descriptions of the individual **component states**, the state of the **fuel management system** and the state of the **fuel management modes**.

Each component has an individual state description. A **two-position control valve** for example will have **four** states: **open, closed, travelling** and **failed**.

System states exist for **individual tanks** and the complete fuel system. The state of an **individual tank** is described as follows**: below low level**, **between low and high level** and **above high level**.

The fuel management **modes** like **engine-supply** are stated as follows: **mode active**, **mode inactive** and **mode aborted**. Within ***SmartFuel*** the modes **pressure refuel, engine supply** and **transfer/balancing** will be investigated.

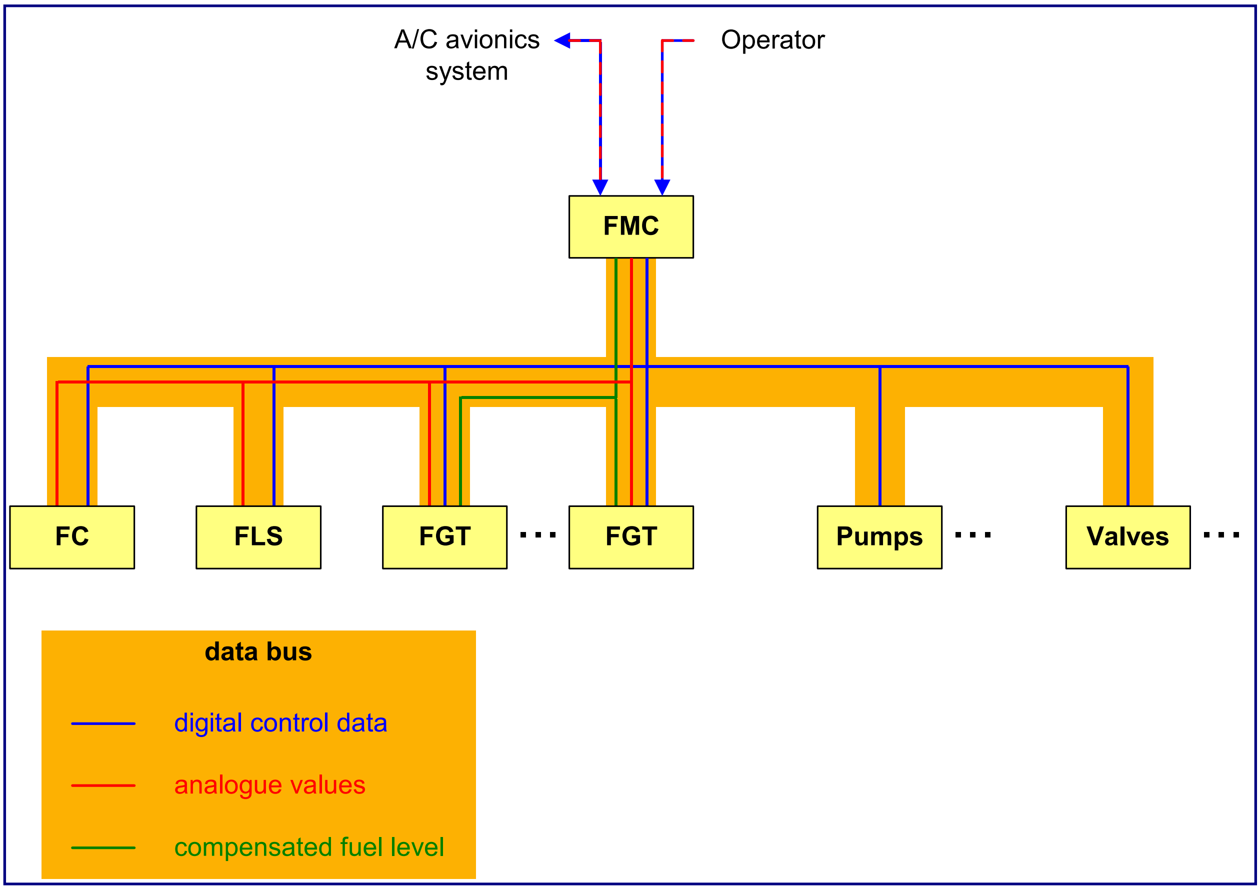


Fig 10 Information Interchange

Fig 11 State Vector

- description of component states
- description of system states
- description of mode states

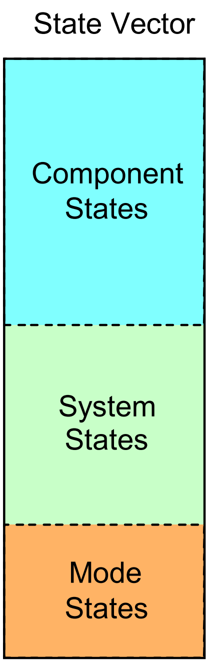
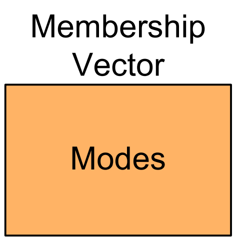


Fig 12 Membership Vector

- specific for each component
- describes if the components is affected by the respective mode
- message filter



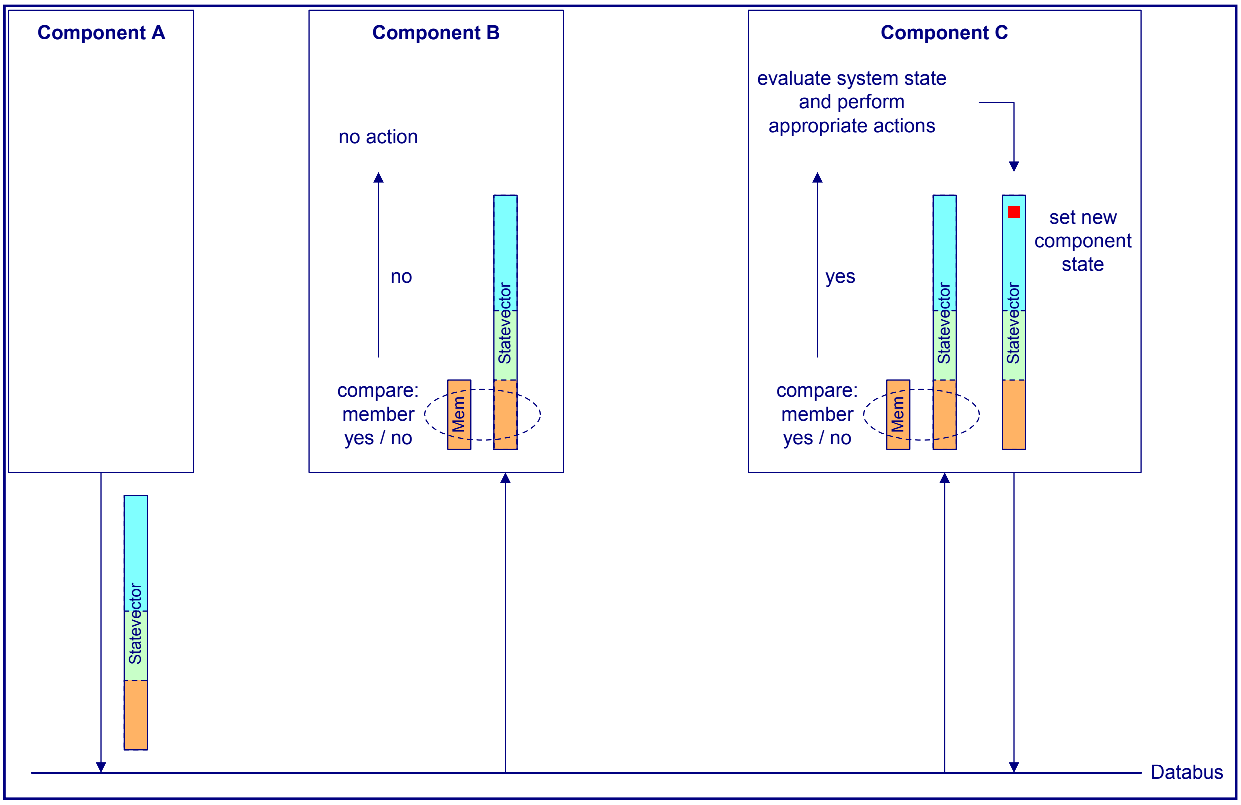


Fig. 13 State Change Sequence

A typical state change sequence is show in Fig. 13 above.

It is assumed the component A changes its state due to a required operation. Component A sends the modified state vector via the bus to the other nodes.

Component B reads the updated state vector and decides on its membership vector that no action is required.

Component C reads the updated state vector and decides on its membership vector that an action is required. Component C performs the required action, sets the new component state within the state vector and transmits an updated state vector via the bus to all the nodes.

8. Validation

The ***SmartFuel*** system architecture and operation principle will be **validated** by means of **numerical simulation** and **wet testing** in a **fuel rig**.

The following **critical modes** will be validated on the fuel rig (see Fig 14 below):

- Pressure Refuel
- Engine Supply
- Transfer (sub-mode of Pressure Refuel.

Validation of the **optimised center-of-gravity control** and **balancing function** using **a smart positional valve** will be validated by **numerical simulation** of a fixed wing configuration.

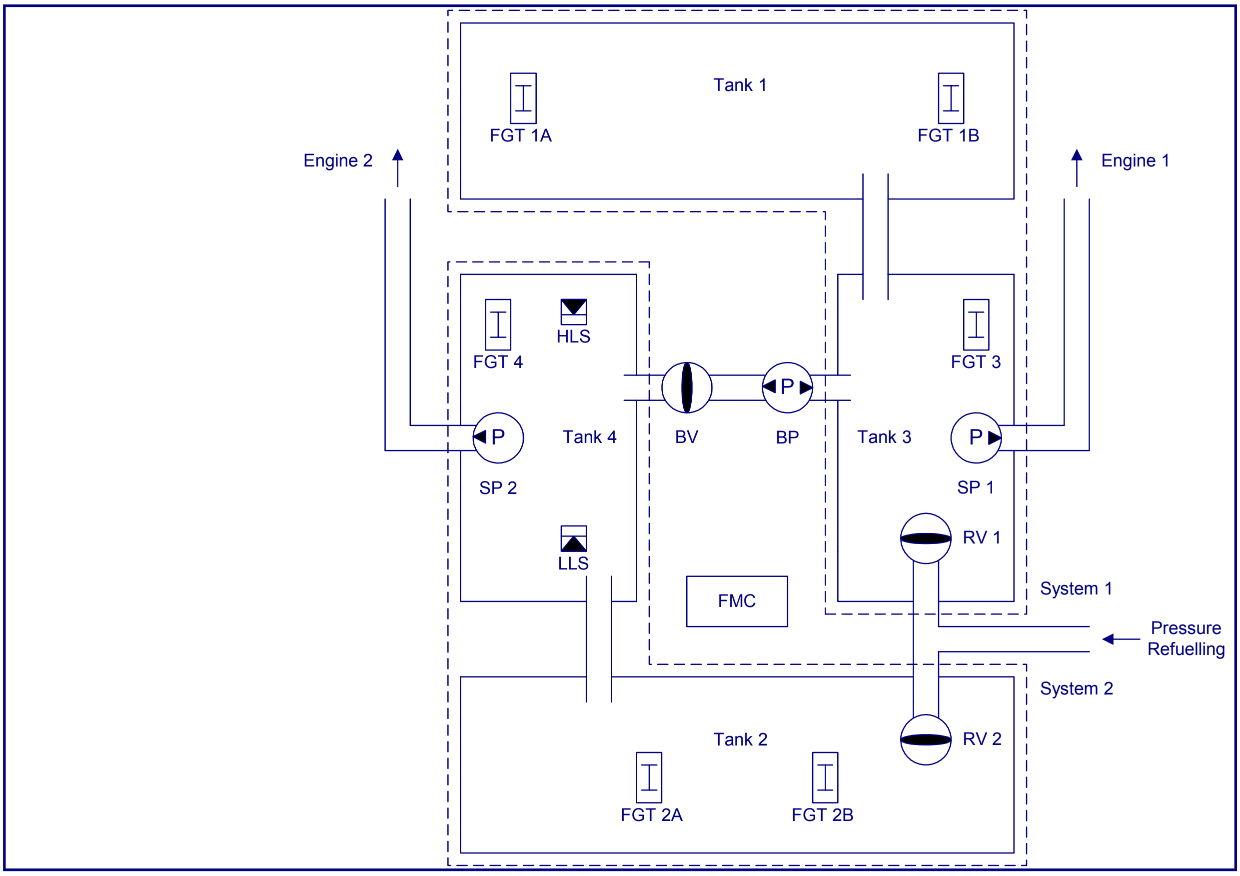


Fig. 14 ***SmartFuel*** Validation System Architecture

Legend:

BV	Balance Valve
BP	Balance Pump
SP	Supply Pump
RV	Refuel Valve
FGT	Fuel Gauge Transmitter
LLS	Low Level Sensor
HLS	High Level Sensor
FMC	Fuel Management Controller
SY	System
T	Tank

9. Summary

The ***SmartFuel*** project currently is in transition from the definition to the realisation phase. The **definition tasks** of workpackage 1 have been finished.

The **protocol definition** of workpackage 2 will overlap with the **smart components & computer** realisation, which is scheduled for the second year of project.

The ***SmartFuel*** validation by rig testing and numerical simulation is planned to finalise the project after three years.

As a result of the ***SmartFuel*** project the consortium will be in the position to offer to rotary and fixed wing manufactures **smart liquid management systems** with **rapid response time** and **superior availability** together with **improved EMC, reliability** and **less weight** for a **lower price**.