ASTRAEA

Autonomous Systems Technology Related Airborne Evaluation & Assessment

Use of MathWorks tools for Prognosis and Health Management Technology within ASTRAEA

BAE SYSTEMS

FLIGHT REFUELLING

THALES

BAE SYSTEMS

Rolls-Royce

EADS

QinetiQ

Loughborough University

University of Leicester

Prifysgol Aberystwyth University

Agenda

- ASTRAEA overview
- Fuel Model Example
- Demonstration
- Next Steps
- Lessons Learnt
- Conclusions
- Further Information

What is ASTRAEA

- **Objective**
  - **to enable the opening up of the UK and European airspace to the routine use of UAVs, without the need for special / restrictive conditions of operation.**
- **Phase 1:**
  - **3 year programme 2006-2008**
  - **£32M programme, Funded 50% industry 50% government (TSB,NWDA,WAG,SE,SWRDA,SEEDA). BAE Systems is approx 30%.**

ASTRAEA Partners

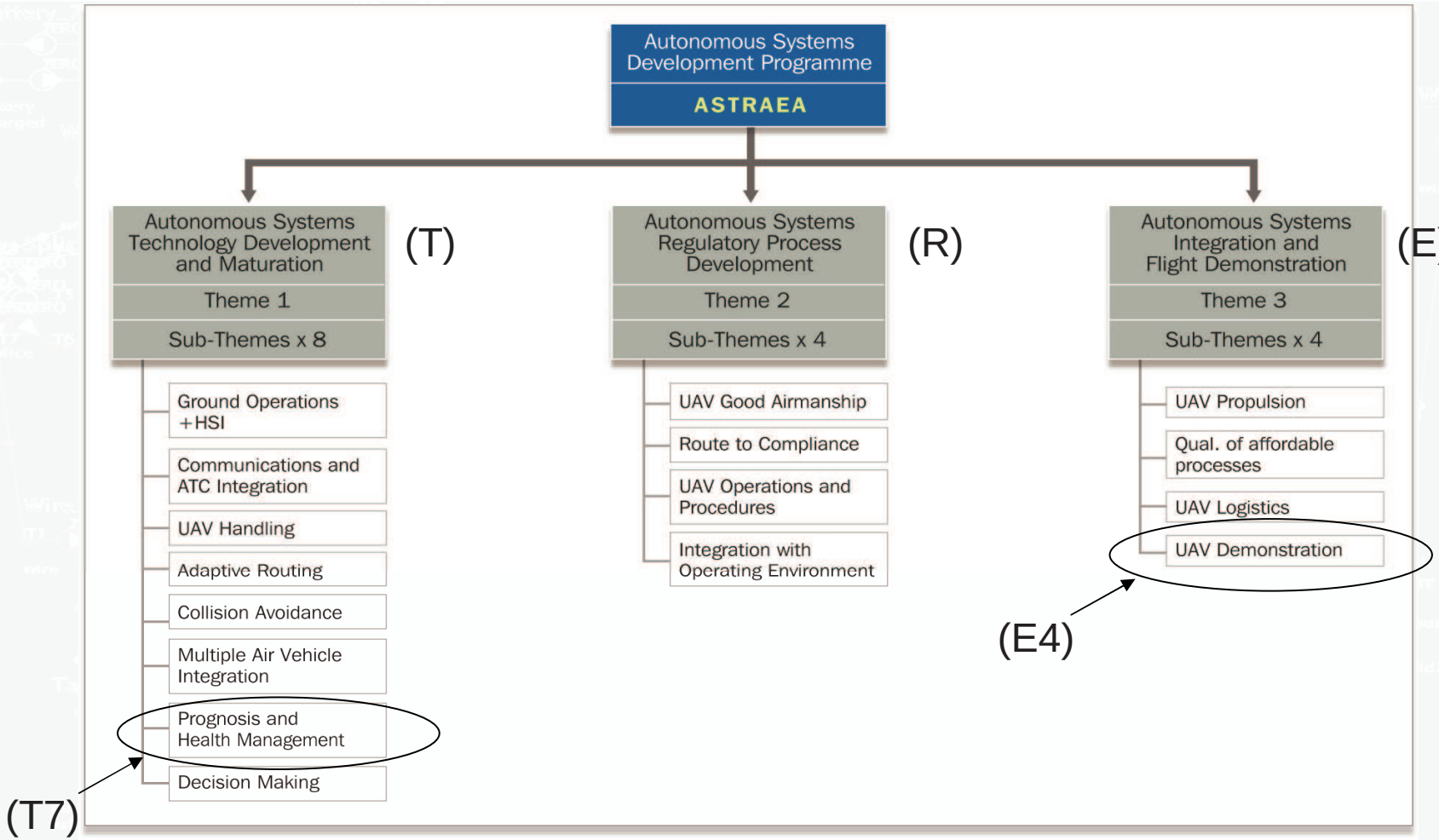
- **BERR / TSB**
- **Regions**
  - Welsh Assembly Govt
  - Scottish Enterprise
  - SEEDA
  - SWRDA
  - NWDA
- **CAA**

- **Industry**
  - Agent Oriented Software
  - BAE Systems
  - EADS
  - Flight Refuelling
  - QinetiQ
  - Rolls-Royce
  - Thales

- **Universities**
  - Cranfield
  - Lancaster
  - Leicester
  - Loughborough
  - Sheffield
  - West of England

60 Subcontract SMEs and Universities

ASTRAEA Organisation



T7: Prognostics & Health Management

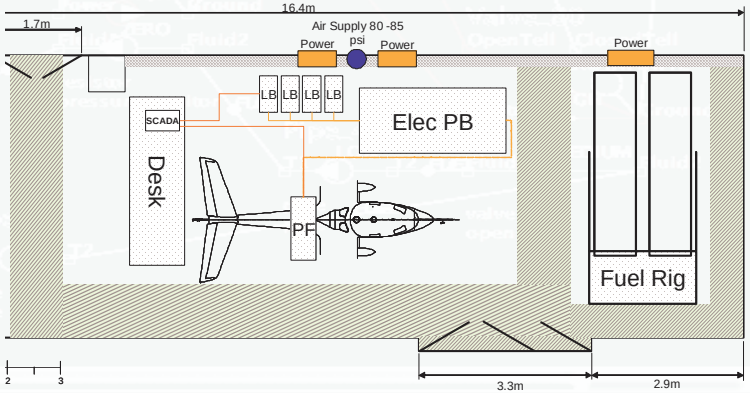
T7 aims to provide technology and systems so that UAVs can

- **monitor their own state,**
- **perform real-time prognosis of their immediate and future capabilities,**
- **make decisions on how best to assist the optimal mission performance.**

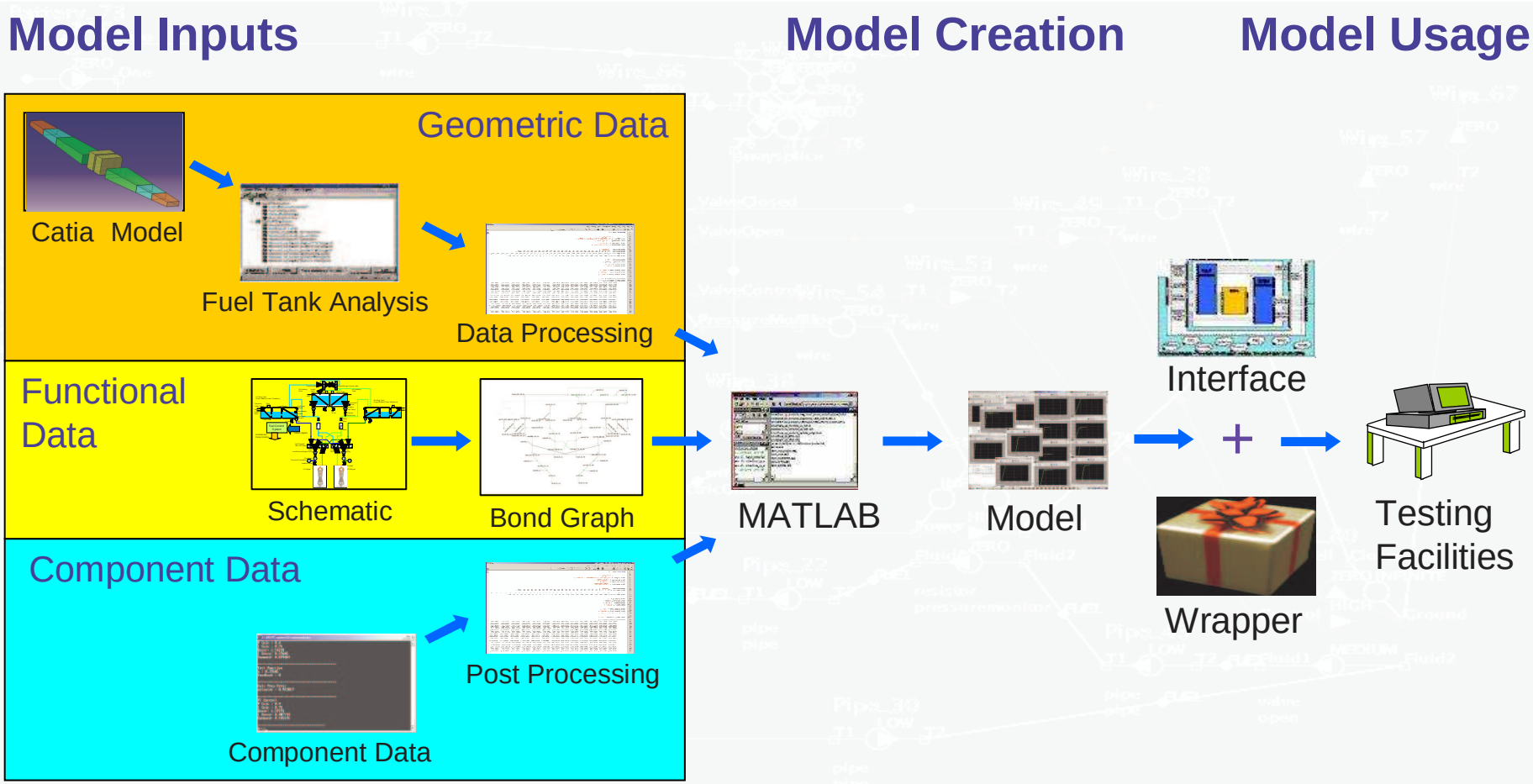
E4: UAV Demonstration

Under E4 sub-theme the BAE SYSTEMS-Air System will demonstrate ASTRAEA Technologies using the following:

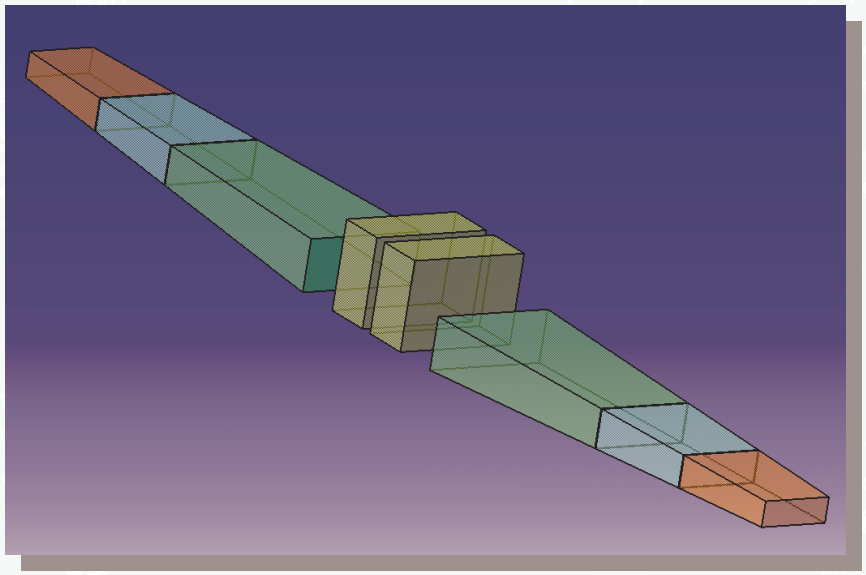
Synthetic Environment
System Integration Laboratory
Flying Demonstration



Fuel Model Design Process

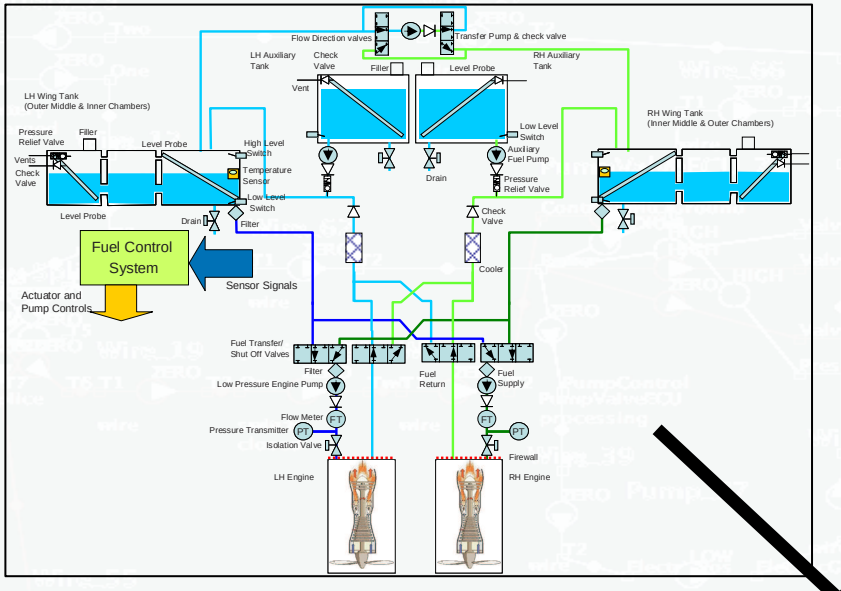


Geometric Data

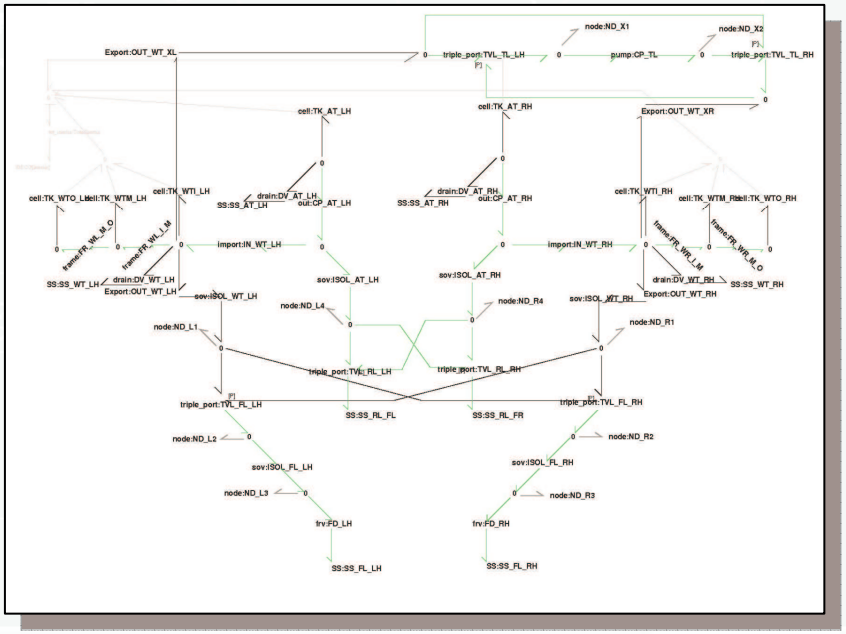


- Tanks are simple fuel solids (no pipe work or components subtracted)
- Centre tanks are single cell tanks
- Wing tanks are three cell tanks

Functional Data

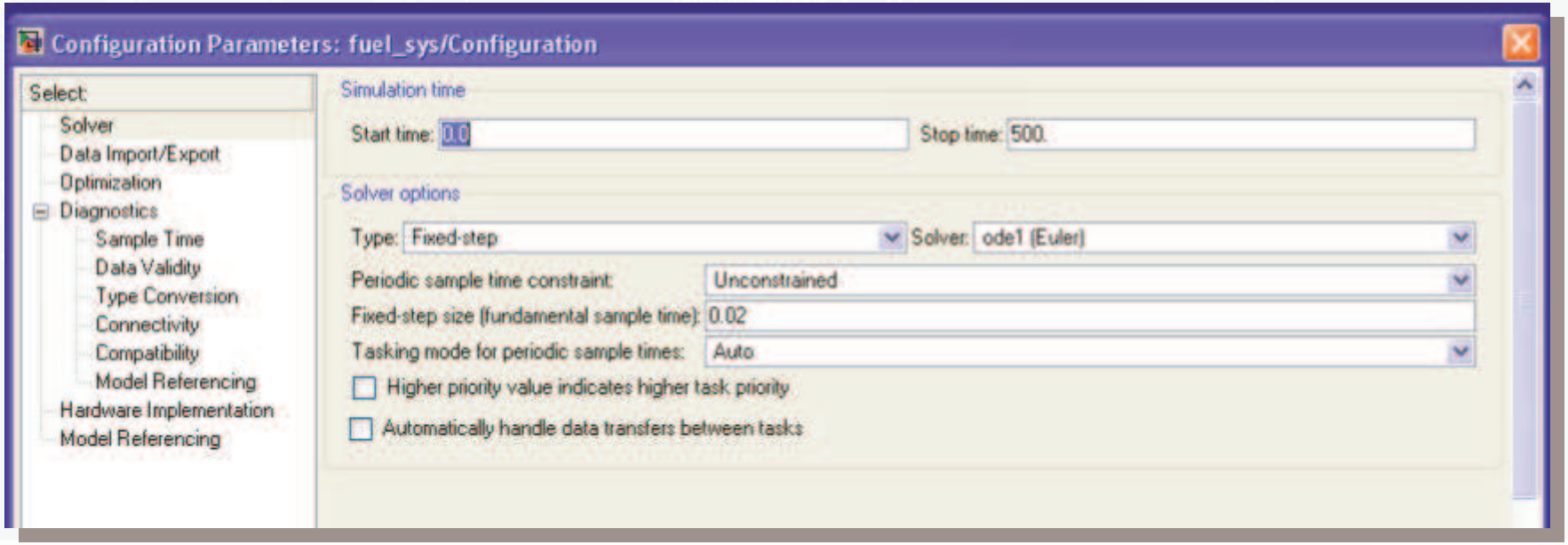


A Fuel Schematic is translated into a bond graph schematic with associated text file detailing the components which is then compiled into a model using MATLAB

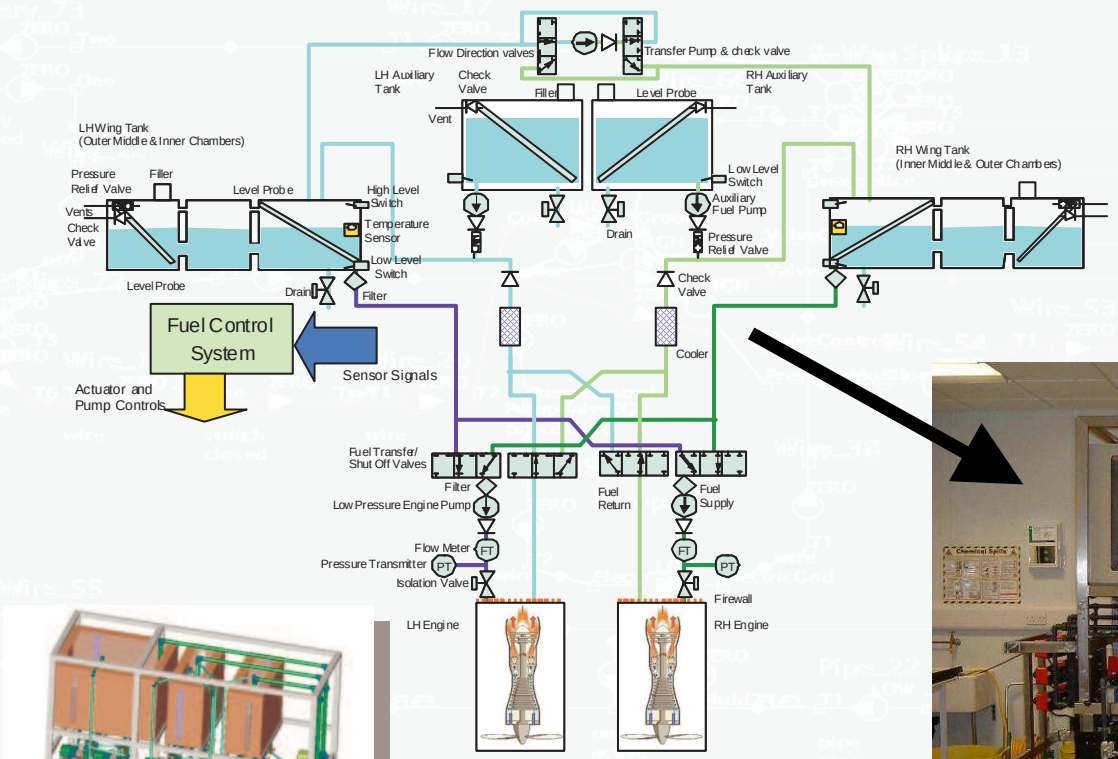


Model Creation

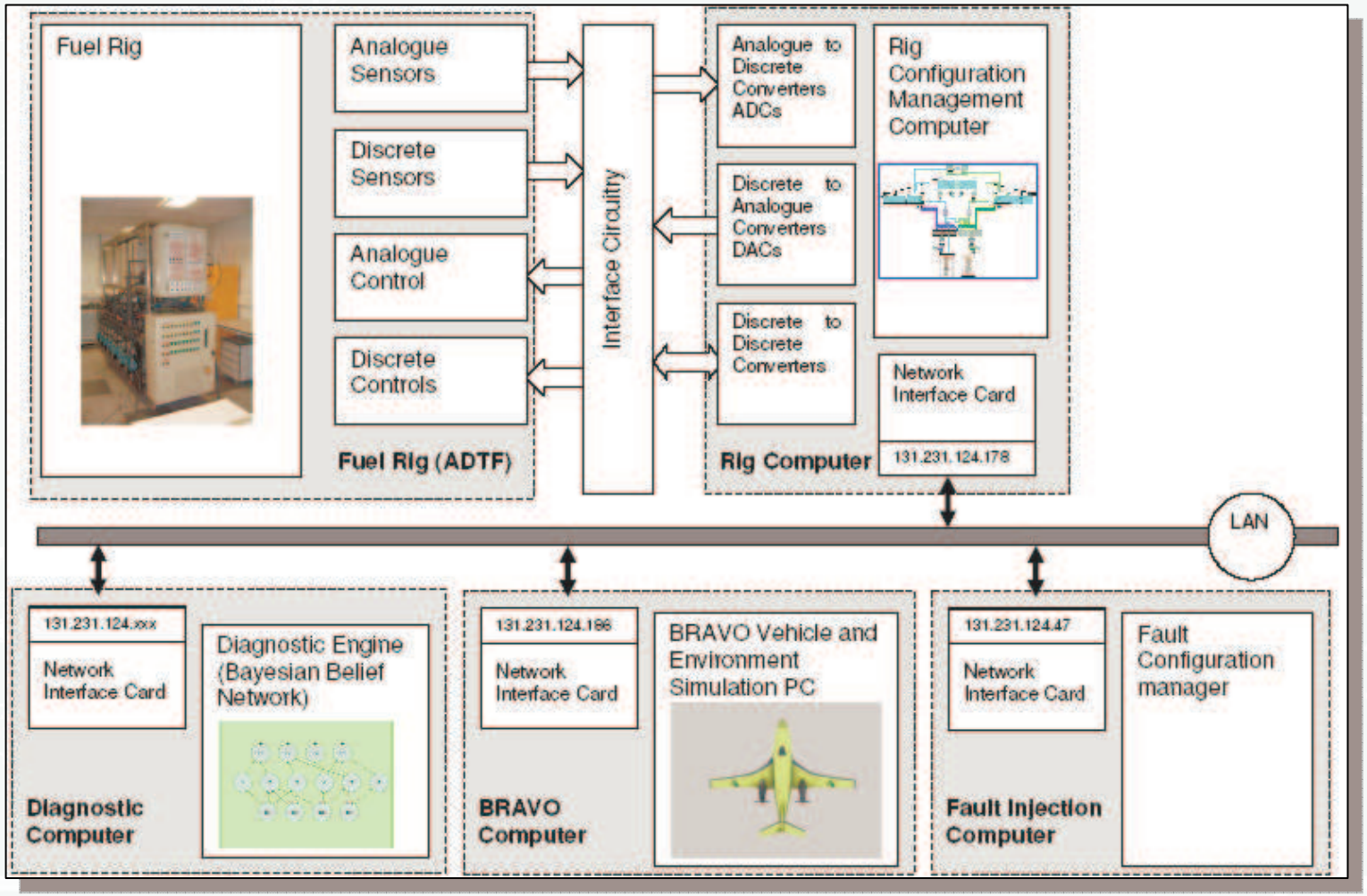
- The input data is processed by MATLAB in order to create a set of system equations followed by creation of the Simulink model and s-function generation.
- Once compiled the s-function can be run within Simulink using the configuration parameters below:



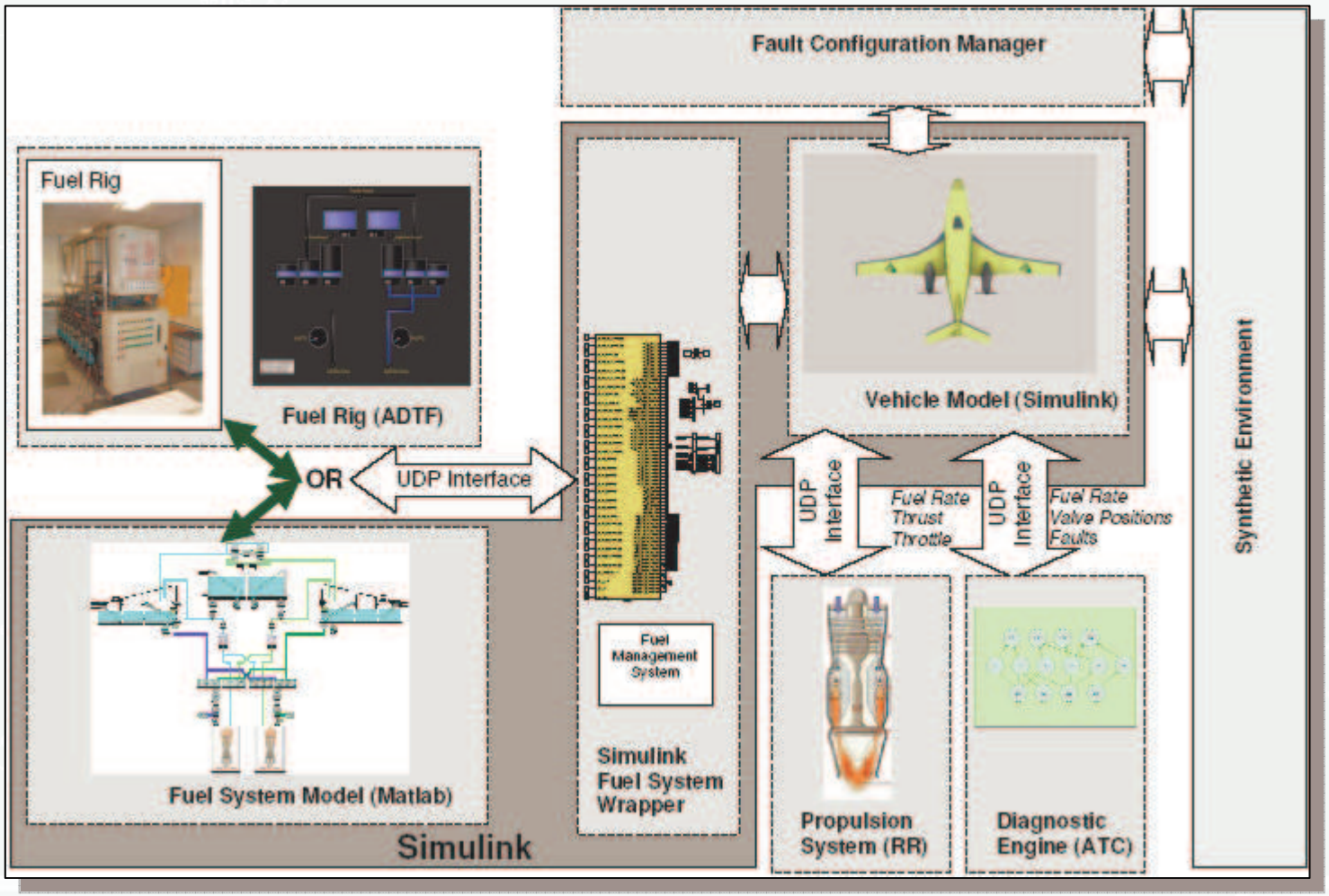
Fuel Rig


Flow Direction valves
Transfer Pump & check valve
LH Auxiliary Tank
Check Valve
Filler
Level Probe
RH Auxiliary Tank
Vent
LH Wing Tank (Outer Middle & Inner Chambers)
RH Wing Tank (Inner Middle & Outer Chambers)
Pressure Relief Valve
Filler
Level Probe
High Level Switch
Temperature Sensor
Low Level Switch
Auxiliary Fuel Pump
Pressure Relief Valve
Vents
Check Valve
Drain
Filter
Check Valve
Cooler
Fuel Control System
Sensor Signals
Actuator and Pump Controls
Fuel Transfer/ Shut Off Valves
Filter
Low Pressure Engine Pump
Fuel Return
Fuel Supply
Flow Meter
Pressure Transmitter
Isolation Valve
Firewall
LH Engine
RH Engine

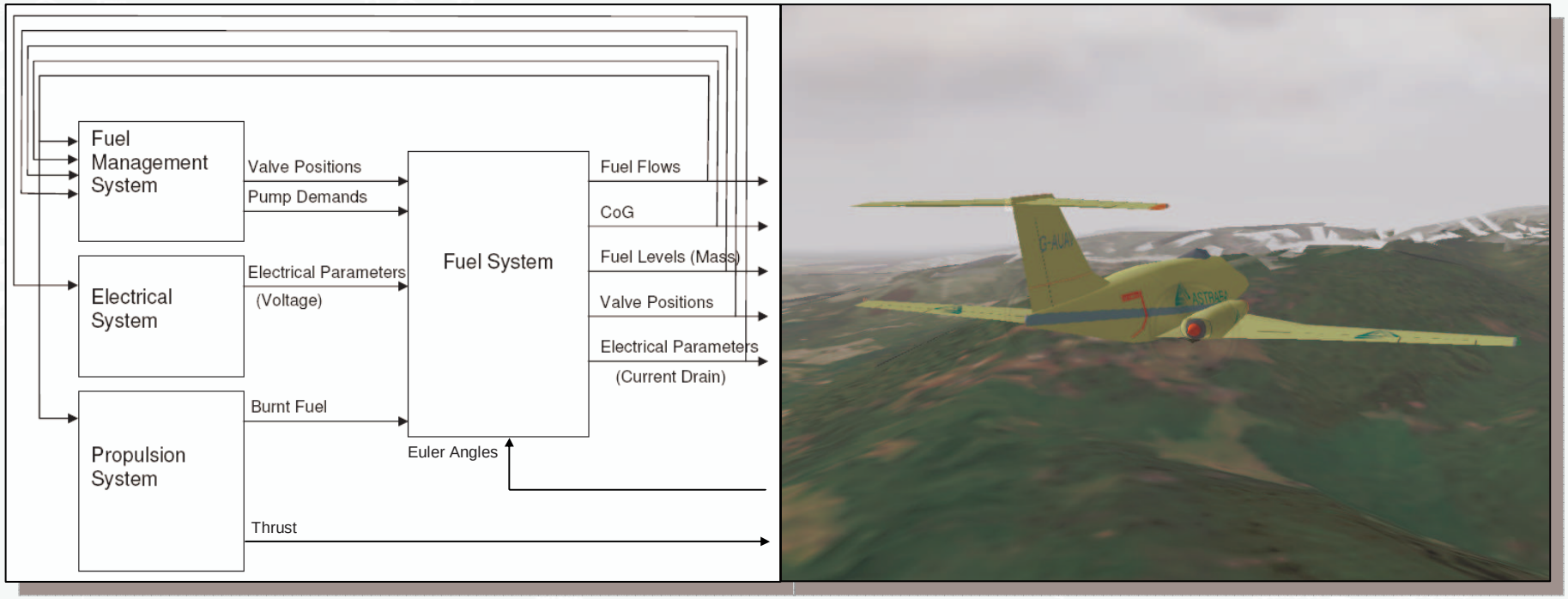
Fuel Rig

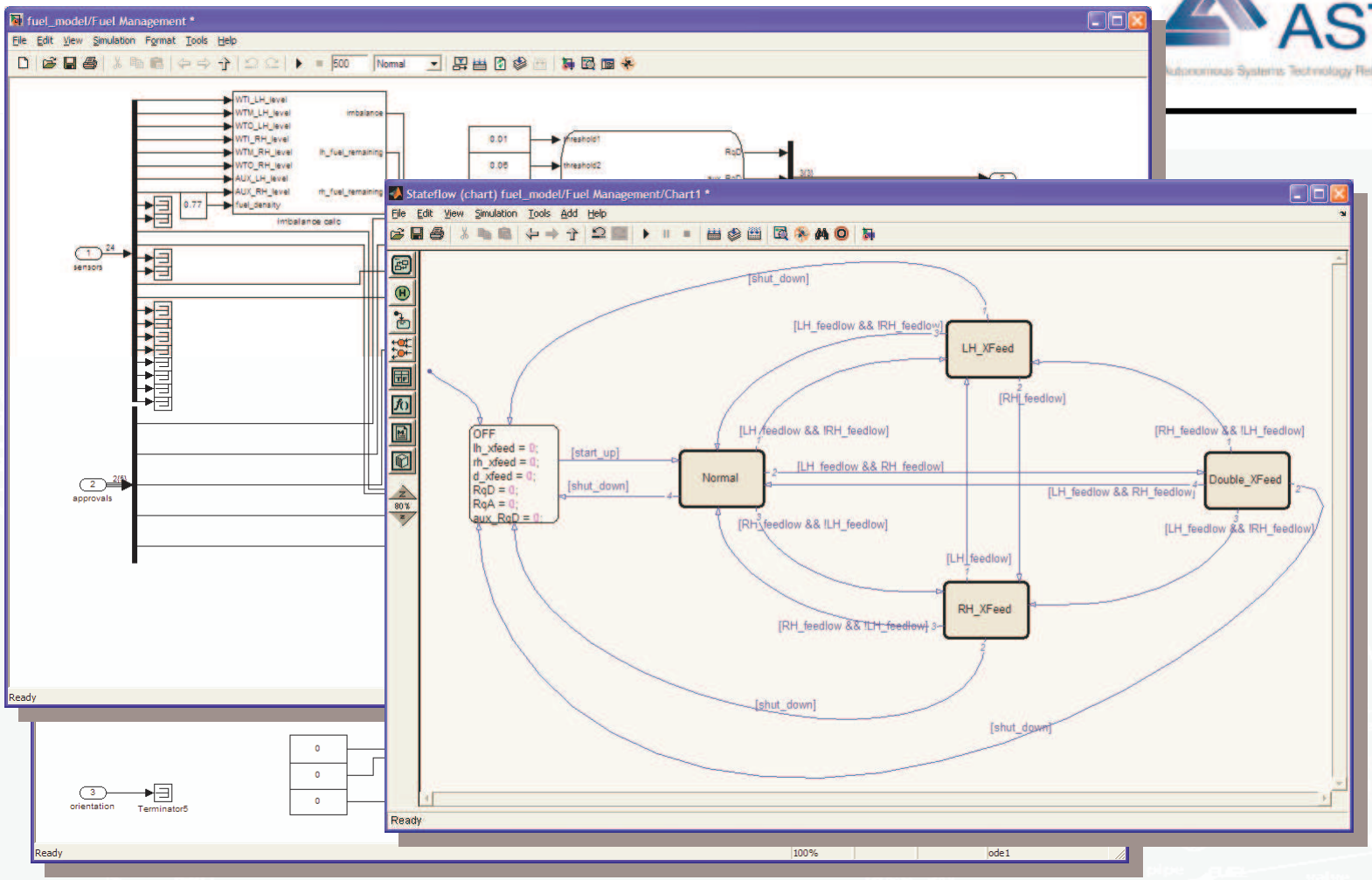

Fuel Rig
Analogue Sensors
Discrete Sensors
Analogue Control
Discrete Controls
Fuel Rig (ADTF)
Interface Circuitry
Analogue to Discrete Converters ADCs
Discrete to Analogue Converters DACs
Discrete to Discrete Converters
Rig Configuration Management Computer
Network Interface Card
131.231.124.178
Rig Computer
LAN
131.231.124.xxx
Network Interface Card
Diagnostic Engine (Bayesian Belief Network)
Diagnostic Computer
131.231.124.186
Network Interface Card
BRAVO Vehicle and Environment Simulation PC
BRAVO Computer
131.231.124.47
Network Interface Card
Fault Configuration manager
Fault Injection Computer

Fuel Rig


Fault Configuration Manager
Fuel Rig
Fuel Rig (ADTF)
OR
UDP Interface
Vehicle Model (Simulink)
Synthetic Environment
UDP Interface
Fuel Rate
Thrust
Throttle
UDP Interface
Fuel Rate
Valve Positions
Faults
Fuel Management System
Simulink Fuel System Wrapper
Fuel System Model (Matlab)
Simulink
Propulsion System (RR)
Diagnostic Engine (ATC)

Fuel Rig


Fuel Management System
Electrical System
Propulsion System
Valve Positions
Pump Demands
Electrical Parameters
(Voltage)
Burnt Fuel
Thrust
Fuel System
Euler Angles
Fuel Flows
CoG
Fuel Levels (Mass)
Valve Positions
Electrical Parameters
(Current Drain)



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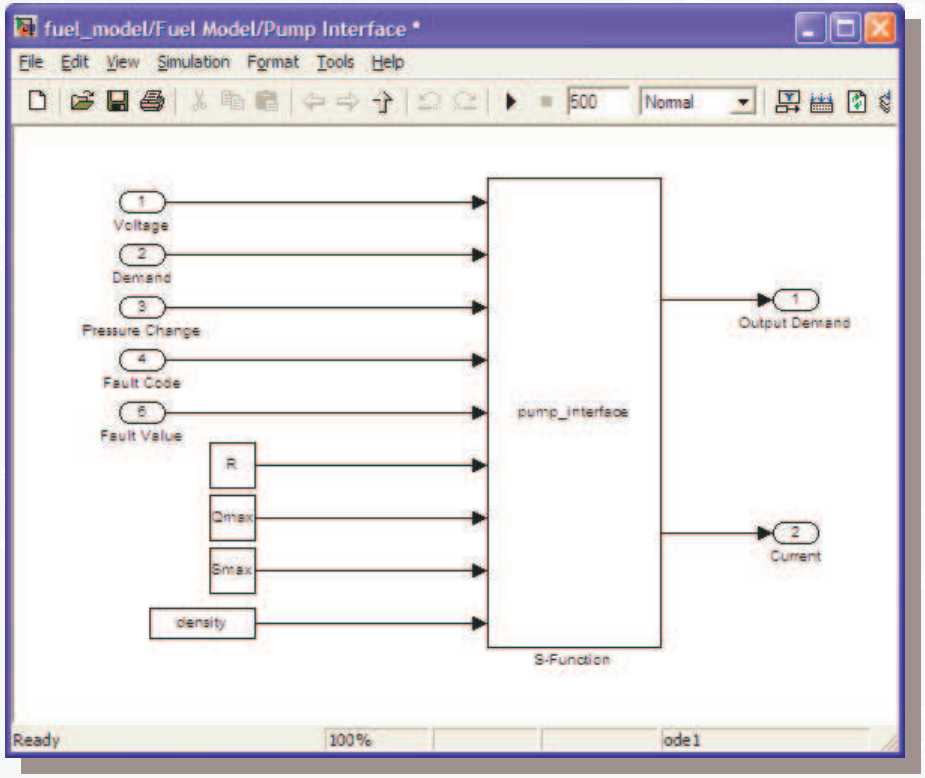
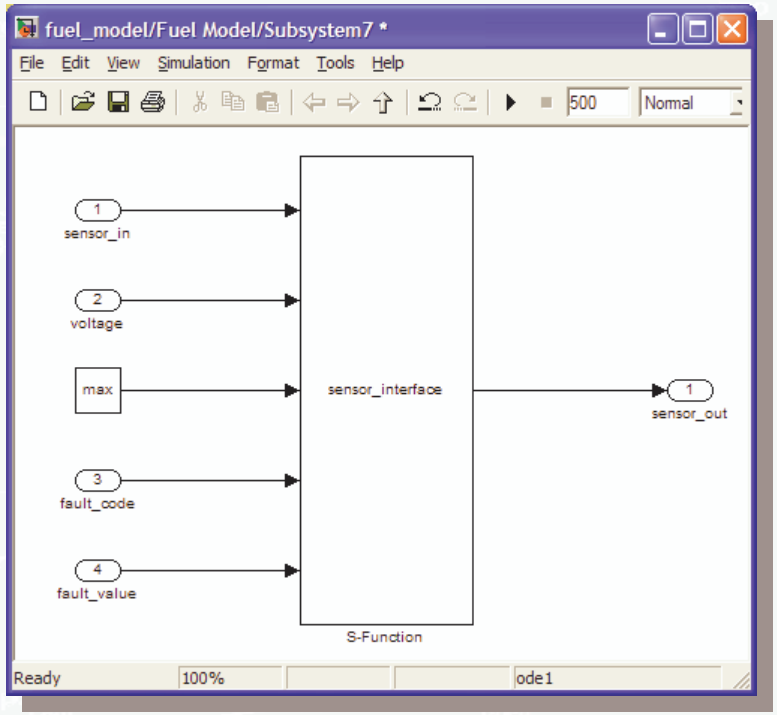
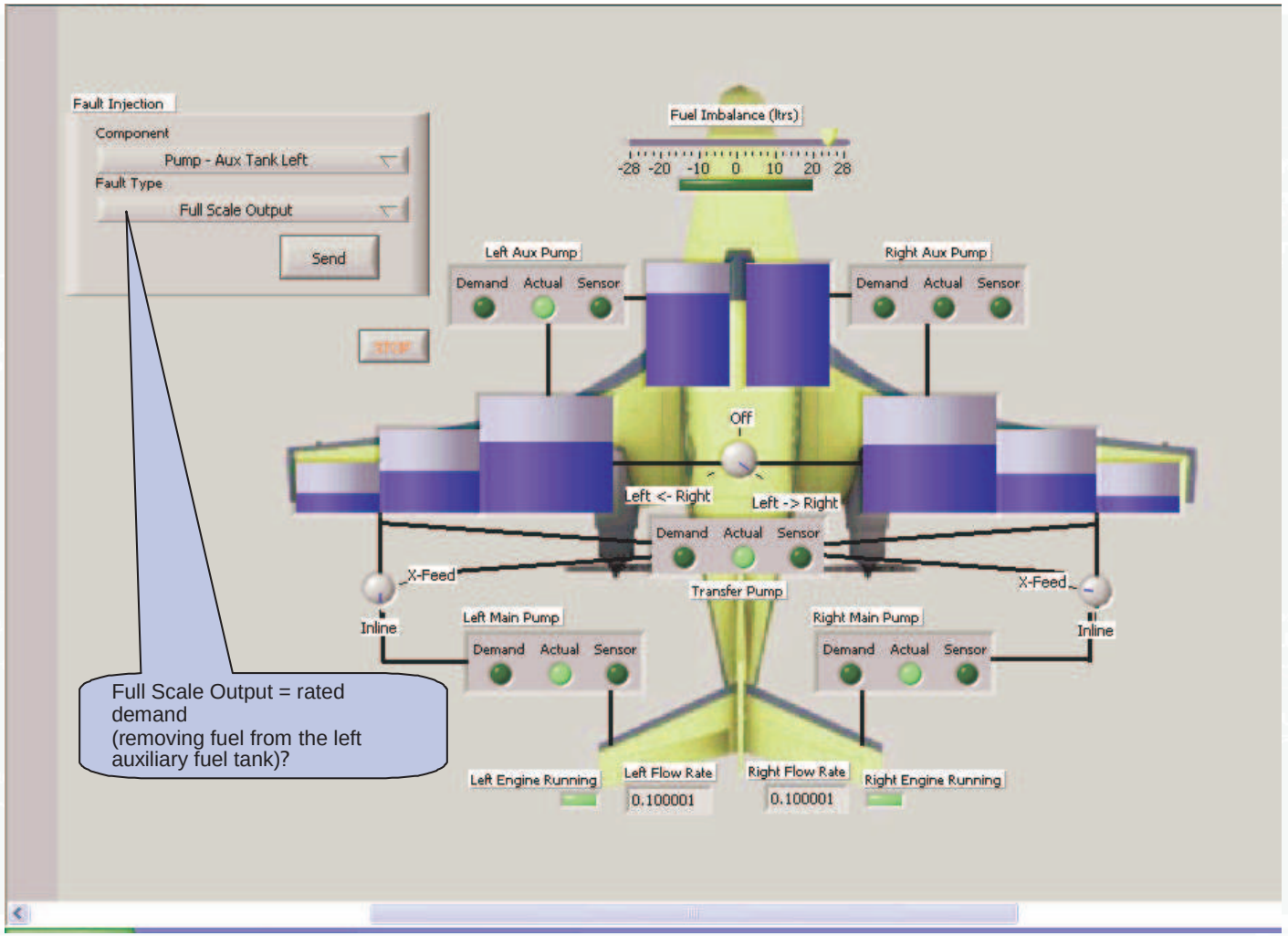
Fault Injection & Monitoring Outputs

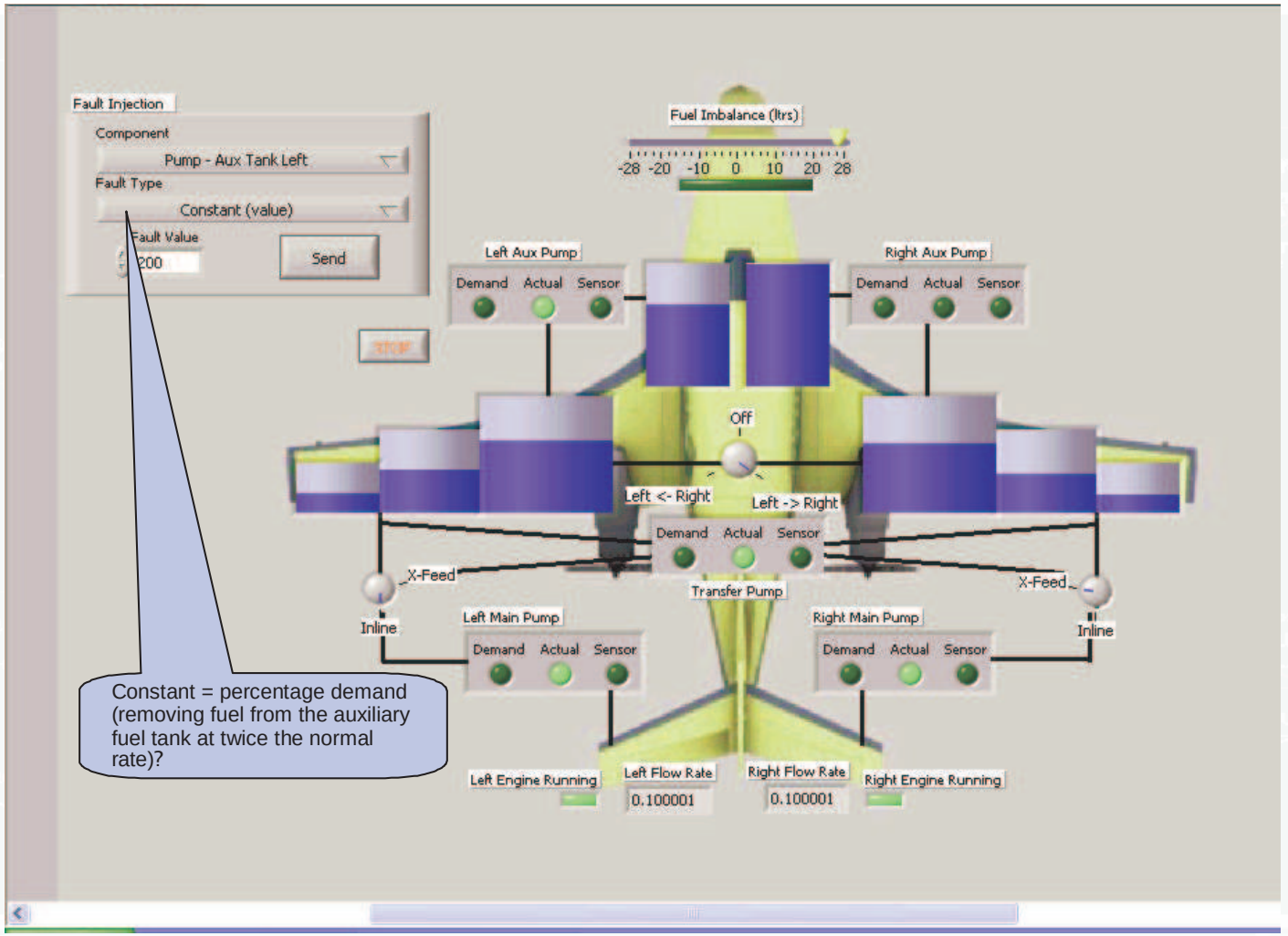




Fault Injection



Fault Injection

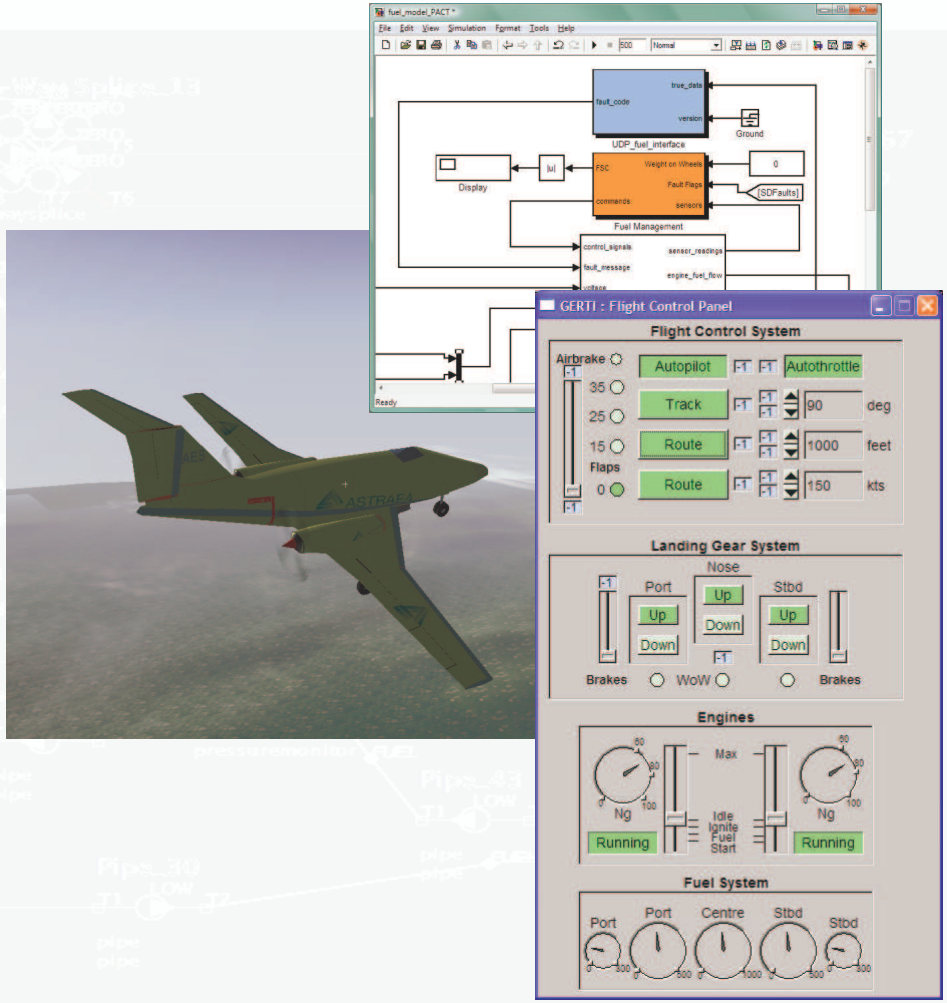


Demonstration

Two mini-demonstrations:-

1. Integrated UAV Bravo – A MATLAB / Simulink flight dynamics model, built using the Real-Time Workshop (RTW), exporting behaviour to X-Plane (single computer).

2. Networked Fuel Model – A MATLAB / Simulink fuel model interacting with fault injection, mission authorisations and visualisation (two computers).



Next Steps

- Construct a large granularity, simplified, electrical system model
- Testing to confirming behaviours for a limited set of scenario based test cases.
- Apply noise models to the fuel prognostics.
- Compare models behaviour to that of the Fuel Systems Rig.

Lessons learnt

- The integration of multiple models from multiple partners remains a challenge within a complex project due to:
  - differences in modelling approaches (physics or scenario based),
  - configuration management
  - MathWorks release compatibility.
- There remain some unresolved (model initialisation) issues encountered when attempting to integrate this sub-model (s-function) with the whole vehicle system within the Real-Time Workshop.

Conclusions

- The Prognostics and Health Management project requires the robust modelling of system failures at a component level in order to validate diagnostic or prognostic methods.
- This methodology, applied to a Fuel Systems model, has demonstrated
  - computationally fast, embeddable model for use within a larger Simulink vehicle system model
  - the benefit of the available code generation tools for rapid prototyping
- Producing a model that encompasses multiple features, whilst accommodating a variety of modelling approaches suggests that it is convenient to use a selection of custom tools.
- The MathWorks Simulink tool provides an excellent environment within which to rapidly prototype and test system models.

Further Information

- http://www.projectastraea.co.uk/