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Wrapping the Future

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OTS Components

- OTS (Off The Shelf) software components:
  - Are relatively cheap, because of price amortisation
  - Can come with extensive records of use
  - Are Immediately available
- But:
  - Previous use might not be representative
  - Information about their development process may be unavailable
  - They may even have to be viewed as black boxes
- So:
  - How can they be used safely in a critical bespoke software system?

The DOTS Project

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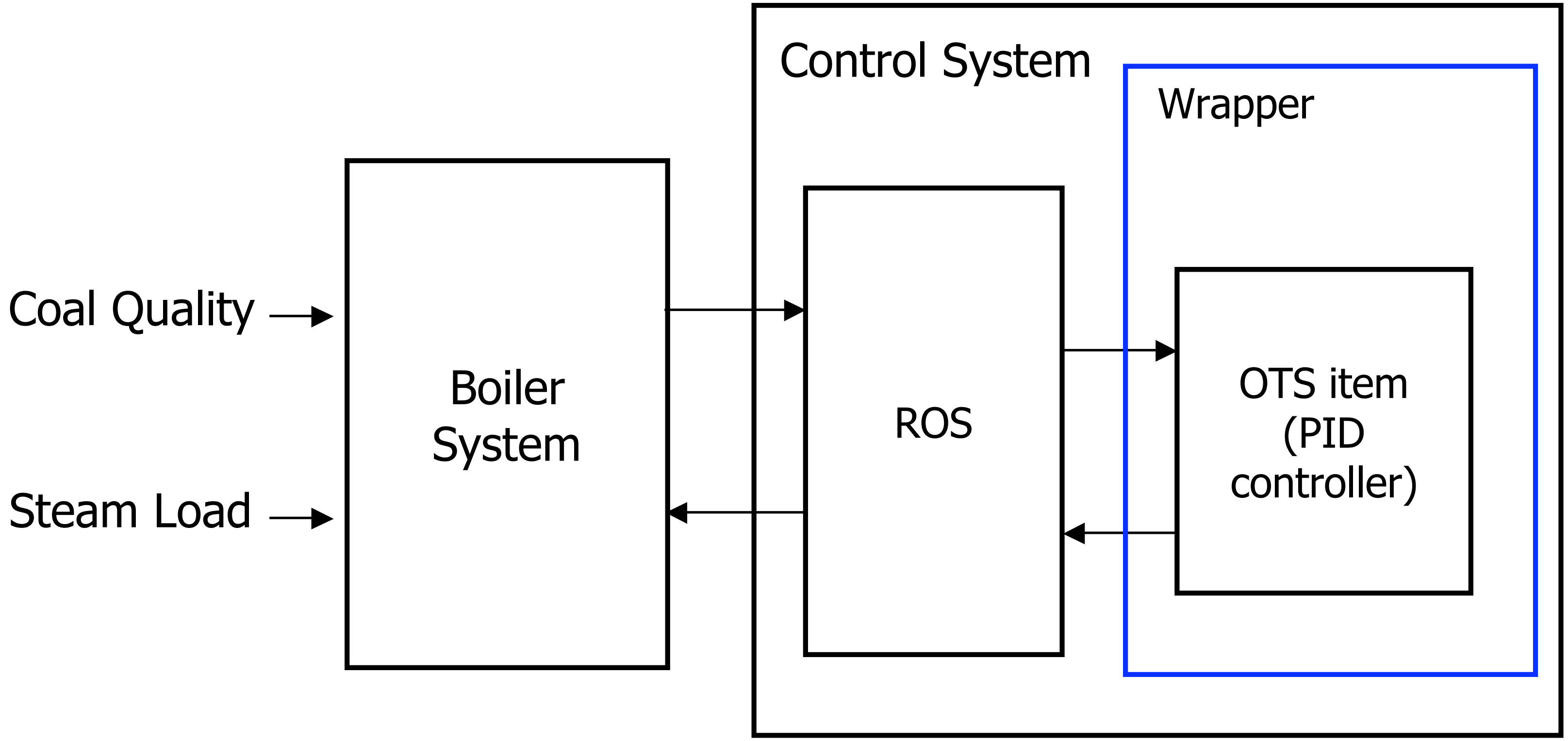
- “Diversity with OTS components”:
  - A joint City/Newcastle project, sponsored by EPSRC
  - Explored an architectural approach to using untrustworthy OTS components in critical applications
  - The approach - enclosing the OTS component in a purpose-built “protective wrapper”
- Such a wrapper:
  - Intercepts all the OTS component’s inputs and outputs
  - Attempts to mask any faults resulting in errors in this I/O
- DOTS addressed the question:
  - How effective is this (simplistic yet popular) technology?

The DOTS Investigation

- Aimed at realism
  - Though not daring to use a *real* critical application!
- Via an industrial model of a RT control system
  - A Honeywell-supplied industrial grade simulation of a steam boiler and its associated control system
  - Written in Simulink
  - Represents a real steam-raising system in which a coal-fired boiler responds to demands for steam
  - The automated control system incorporates a PID (i.e. Proportional, Integral and Derivative) controller
- The PID is the chosen OTS component to be wrapped

The Steam Boiler Model



PID (Proportional, Integral and Derivative) Controller
ROS - Rest of System (smart sensors, actuators, and configuration controls)

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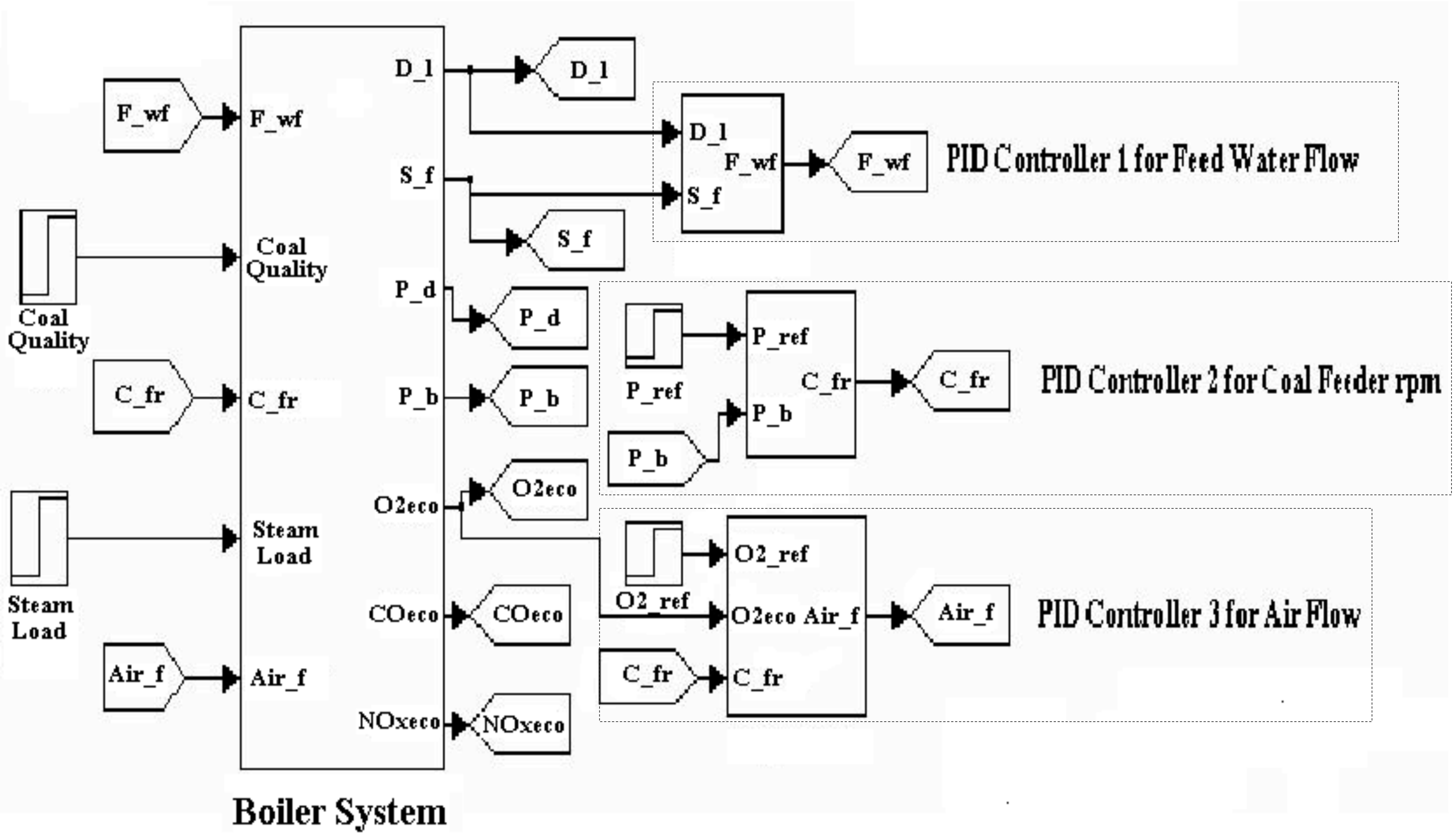
The Simulink Model of Boiler System with PID Controller in MATLAB



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The PID Wrapper

- Monitored, and if necessary, altered all PID I/O
  - The aim - to detect and recover from errors
  - Using limited information about boiler and control system
  - Inner details of PID ignored
  - No access to full external specification of the PID
- Developed an approximate spec. for the PID
  - Based on *Acceptable Behaviour Constraints* (ABCs), of behaviour at PID interface
- Error detection
  - Systematic use of generic criteria

ABCs & Error Recovery

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- Inputs to PID
  - Missing, invalid, unacceptable, marginal or suspect values from the sensors or configuration variables
- Outputs from PID
  - Missing, invalid or unacceptable values intended for the actuators
- (Forward!) Error Recovery
  - Priority given to detected errors which concerned either the steam pressure or the quantity of water in the boiler
- The implemented strategy aimed at realism, but:
  - would need rigorous analysis for an actual boiler plant

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Wrapper-initiated Error Recovery

- Depending on circumstances the wrapper:
  - Shuts down the boiler to a safe state by sending appropriate commands to the actuators
  - Resets the PID or ROS or both to clear a supposed transient problem
  - Alerts operators by ringing alarm
  - Notes problem but takes no any action unless the problem appears to persist

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Some types of Error Cues, with Examples

1. *Illegal output from ROS (according to ROS own specification)*: syntax errors in messages exchanged over the IEEE 488 bus.
2. *Output from ROS is detectably erroneous:* ROS sampling rate suddenly exceeds the specified rate.
3. *Output from ROS is illegal with respect to the system designer's specification of system operation:* PID inputs are outside the envelope of values anticipated by the system designer
4. *Illegal Input to the PID (according to PID's specification)*: syntax errors in messages exchanged over the IEEE 488 bus
5. *Input to the PID is illegal with respect to the PID's specification: S*et point values are mis-configured and violating the PID controller's specification.
6. *Input to the PID which is not fully trusted:* the measured derivative of PID inputs is beyond a certain value which is the maximum value the item has been tested for or lower than the normal performing value.

etc., etc.

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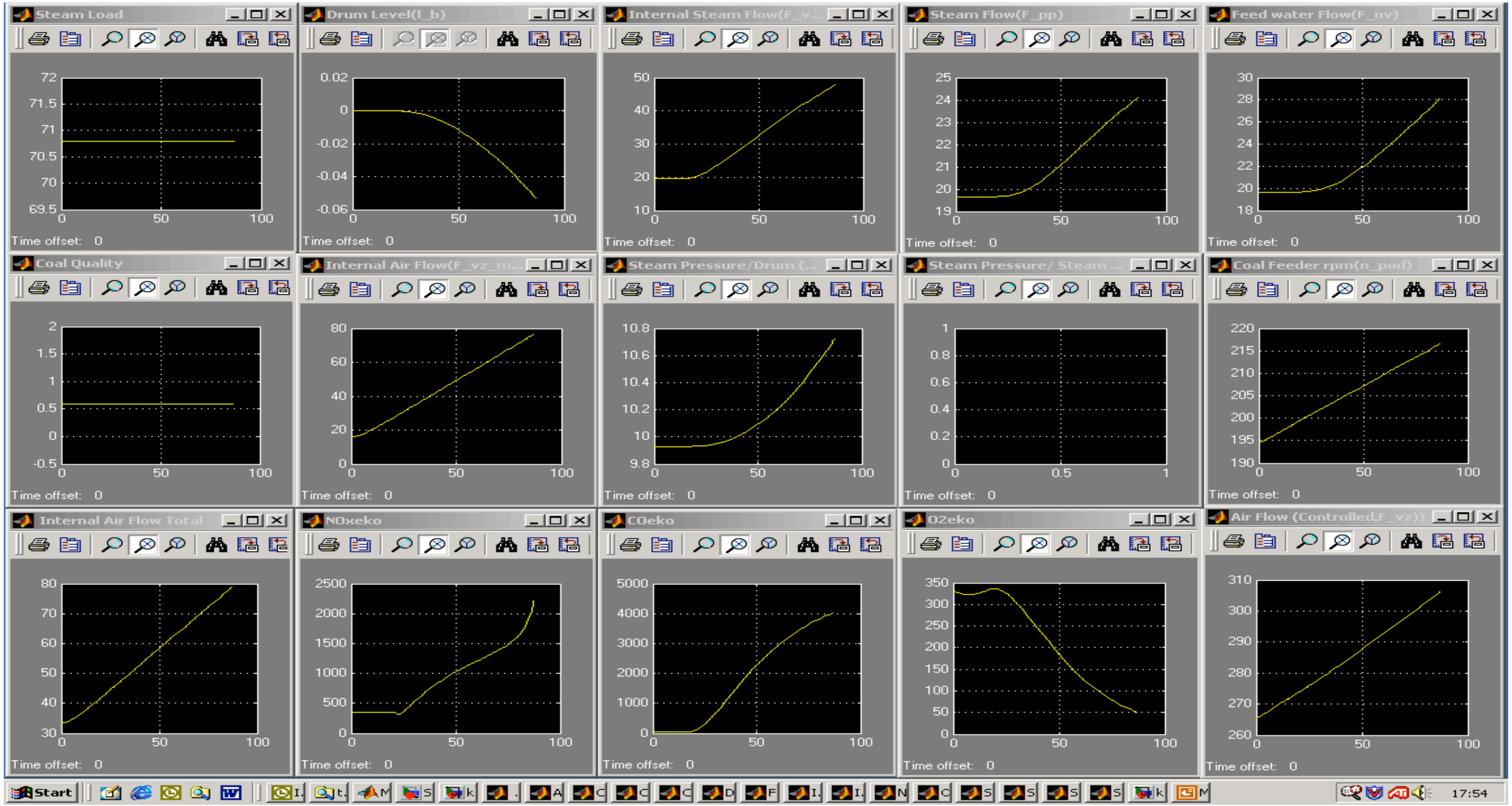
Example of Results

1. Illegal output from ROS (according to ROS own specification)



The process dies, with important variables continuing to increase (or decrease) dangerously.

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Initial Results

- First phase, using a range of fault injection scenarios now completed.
  - The scenarios involve signal communication faults (bias, random noise, stuck-at previous, stuck-at random) and faults affecting the PID’s control algorithms (transient zeros, control parameter overwrites).
- Preliminary examination of the results indicated the wrapper was very effective in reducing serious failures of the boiler system.
  - See:

    Protective Wrapper Development: A Case Study, Anderson, T., Feng, M., Riddle, S., Romanovsky, A. Second Int. Conf. On COTS-Based Software Systems (2003) Ottawa.

    http://www.cs.ncl.ac.uk/research/pubs/trs/papers/781.pdf

Protective wrapping – what next?

- Extend the evaluation of the steam boiler example, and use it to explore:
  - Formal development of wrappers - based on contracts derived from ABCs
  - Timing issues - deadlines and delays
  - Scoping issues - what access might a wrapper have to other variables elsewhere in the system
  - Modelling issues - how to gain confidence in accuracy of the model
  - Safety issues - standards, hazard analysis, safety cases, etc.

Protective Wrapping in Pervasive Systems

- The future is one of huge networked computer systems
  - These are likely to become pervasive, as IT is embedded into virtually everything
  - And to be required to function continuously.
- Our experiments have concerned a typical “closed” safety-critical control system
- But future pervasive systems will need to be “open”, and involve:
  - Online composition
  - Dynamic reconfiguration, evolution and upgrading
- Fault tolerance will be increasingly vital

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Pervasive Systems

- Even the best current development methods are insufficient for such systems
- *Some* promising research directions:
  - Dependability-explicit system development, from first design phases through into deployment
  - Cost-effective formal methods
  - Architecture theory, enabling reasoning at this level about systems and their dependability
  - Adaptivity - dynamic system integration, adjustment and evolution

  (From our recent contribution to the UK Foresight Report on Cyber Trust and Crime Prevention - see http://www.foresight.gov.uk/)
- Protective wrapping - could play a useful role in all the above research topics