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# Overview



# Project Partners



**EPSRC Funded, £3.5 Million, 3 years, commenced Jan 2002.**  
**UK pilot project for e-Science**

**4 Universities:**

- University of York, Dept of Computer Science
- University of Sheffield, Dept of Automatic Control and Systems Engineering
- University of Oxford, Dept of Engineering Science
- University of Leeds, School of Computing and School of Mechanical Engineering

**Industrial Partners:**

- Rolls-Royce
- Data Systems and Solutions
- Cybula Ltd

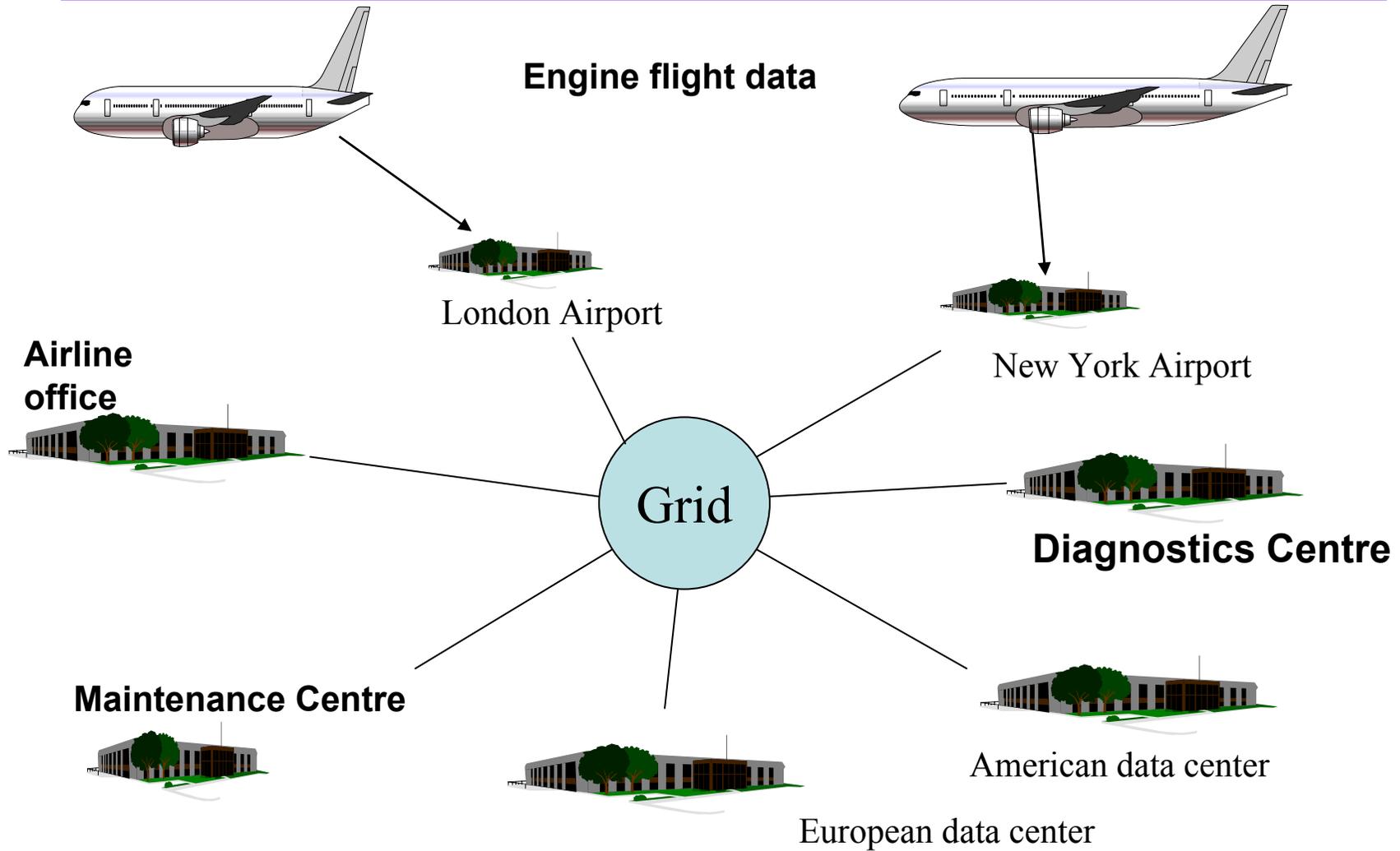


# UK eScience



- £220M programme to develop the technology to support Grid use in the UK
- 6 major Pilot project
- Many other projects
- A number of eScience centres
  - White Rose Grid - £2.8M metropolitan Grid based on Sun and Beowulf clusters
- Next phase of programme taking place later this year

# Operational Scenario





# DAME Grid Challenges



Building a demonstration system as proof of concept for Grid technology in the aerospace diagnostic domain.

Two primary Grid challenges:

- Management of large, distributed and heterogeneous data repositories;
- Rapid data mining and analysis of fault data;

Other key (commercial) issues:

- Remote, secure access to flight data and other operational data and resources;
- Management of distributed users and resources;
- Quality of Service issues (and Service Level Agreements)



# Demonstrator Objectives



The DAME demonstration system will provides a diagnosis workbench (portal) which brings together a suite of analysis services via Grid technology;

- Provides access to a range of analysis tools for the engine diagnosis process
- Acts as central control point for automated workflows
- Manages issues of distributed diagnosis team and virtual organisations
- Manages issues of security and user roles.

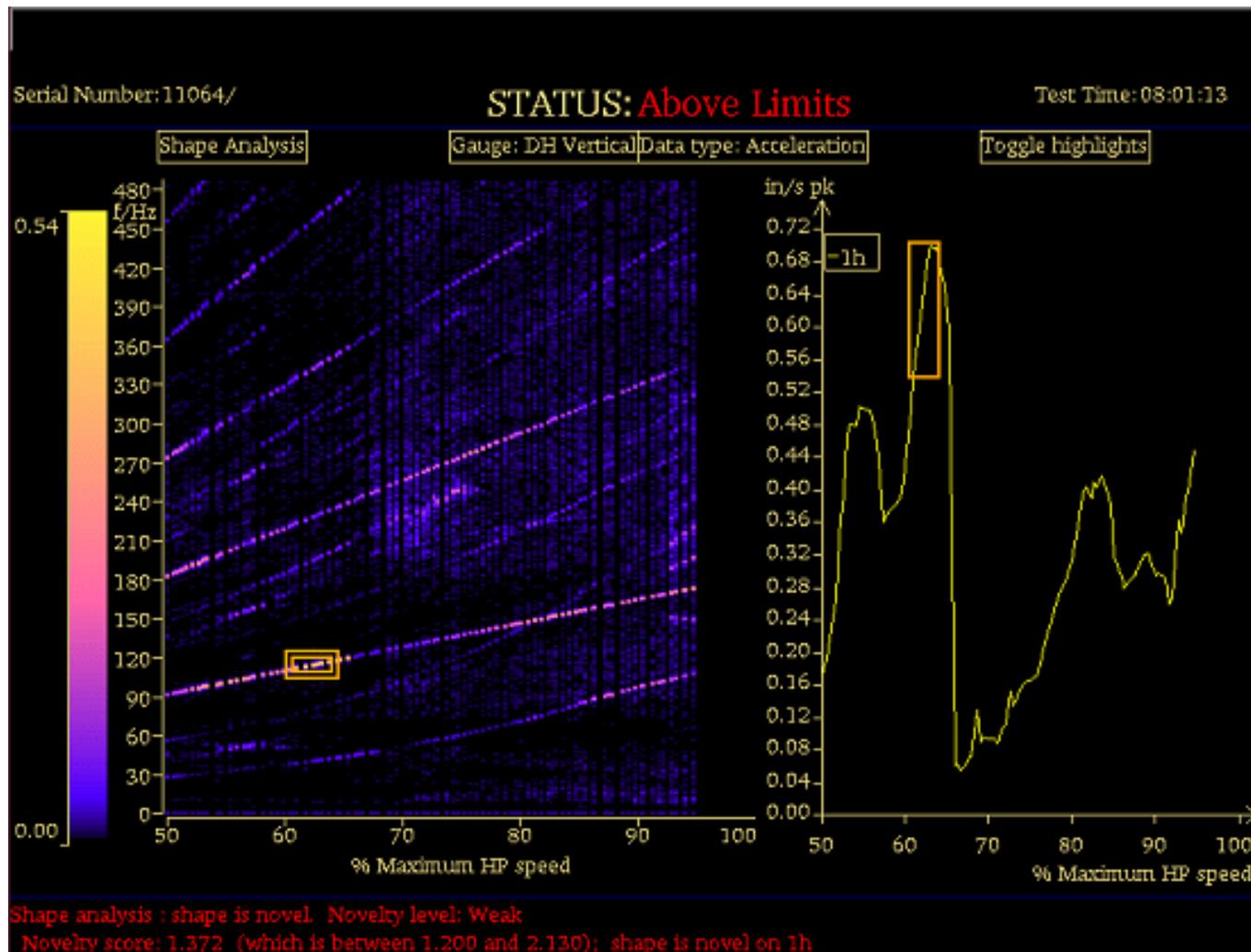


# The Data



- Aircraft generate...
    - up to 1GB of vibration data per engine per flight
    - 4 engines per aircraft,
    - 100 aircraft,
    - 2 flights per day
- Up to 800Gb per day
- Reduced by selection by 10 gives over 30Tb per year.
- This is archived in Engine Data System (EDS)

# The Data



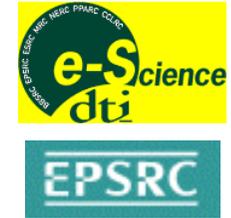


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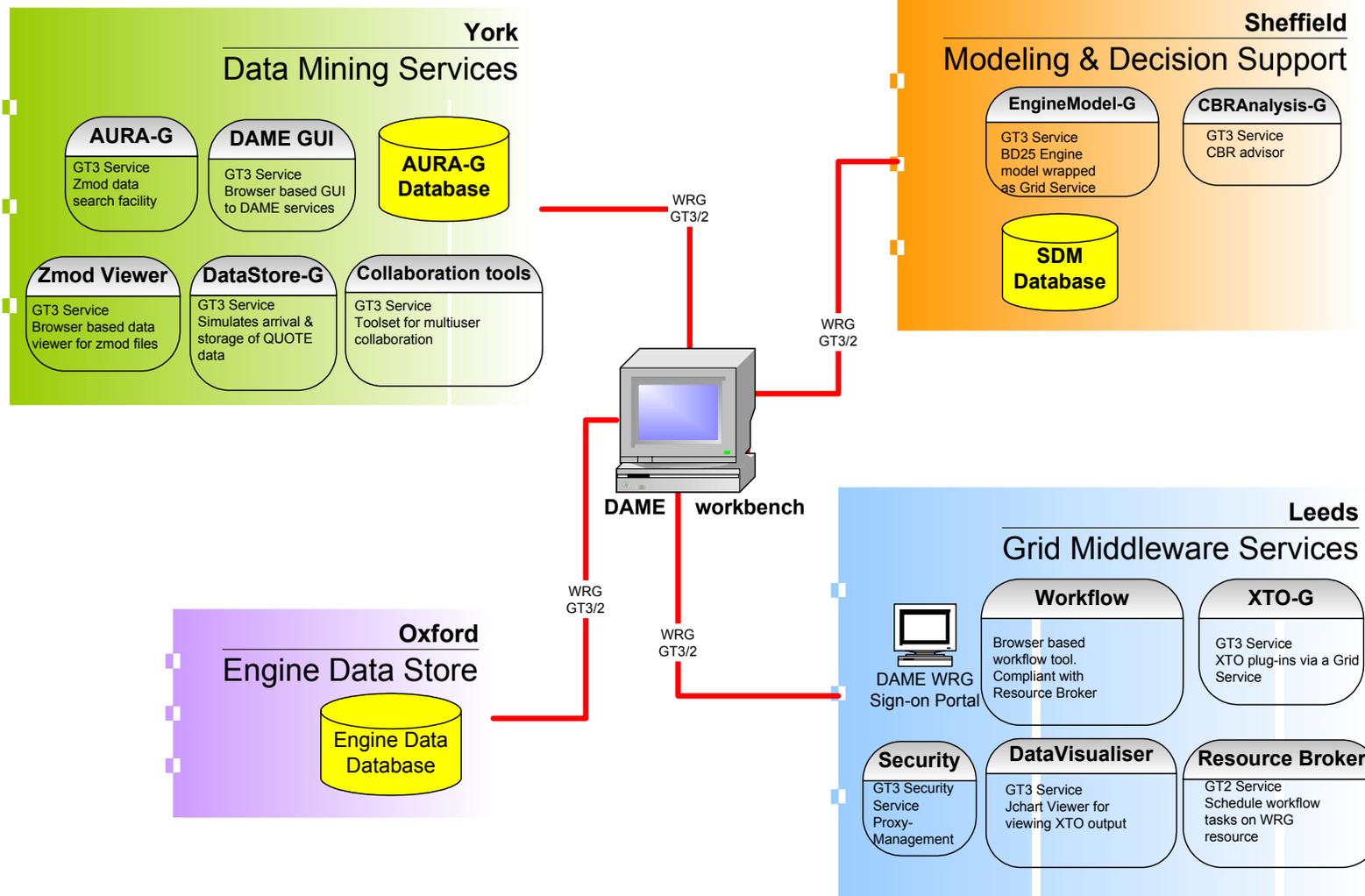
# Services



# Services and Interfaces



- Pattern matching service – AURA
- Pattern Match control service
- Engine Data Explorer - GUI
- Engine Data Store – raw data service
- Case Based Reasoning Service
- Engine Model - service
- Quick signal detector - application
- Workflow engine
- Resource broker





# Pattern matching Service



- The AURA correlation matrix technology is used for rapid pattern matching;
- Two-tier Grid Service architecture.
  - First tier hosts a generic AURA service – for finding the specific instances
  - Second tier retrieves the raw data associated with that instance –based on SRB



Distributed Aircraft  
Maintenance Environment  
DAME

# Signal Data Explorer



DAME Engine Data Explorer

File Edit View Preferences Tools Help

Address <http://pc078.ad.cs.york.ac.uk>

Engine Number: 70003 Date: 22-08-2000 Time: 14:50:00.74 T\_offset: (+00) 15:23:41.14 Y: X:

22 results returned  
Searching for pattern.  
22 results returned  
Pattern found on file: m3088001.111 (Score = 93).

N	Record name	Score	Offset	In
0	70003228 70003228....	490	101	21
1	71017168 71017168....	458	13111	18
2	71010288 71010288....	457	13963	7
3	71010311 71010311....	444	47921	18
4	71010291-2 71010291...	434	36319	11
5	71010184 71010184....	420	45617	0
6	71010298 71010298....	409	45	12
7	71010161 71010161....	407	1887	10
8	71010208 71010208....	406	37289	5
9	71010281 71010281....	404	57709	8
10	71010198 71010198....	403	1105	6
11	71010308 71010308....	401	75	13

Feature Selection: Tracked Orders

Control: SEARCH

Scaling: [Slider]

Speed: [Slider]

LP1  
IP1  
HP1  
LP Total  
IP Total  
HP Total  
Broad Band  
Customize

Find Pattern

Pattern Name

- Acceleration
- Engine Start
- Broad band bird strike
- Testing pattern

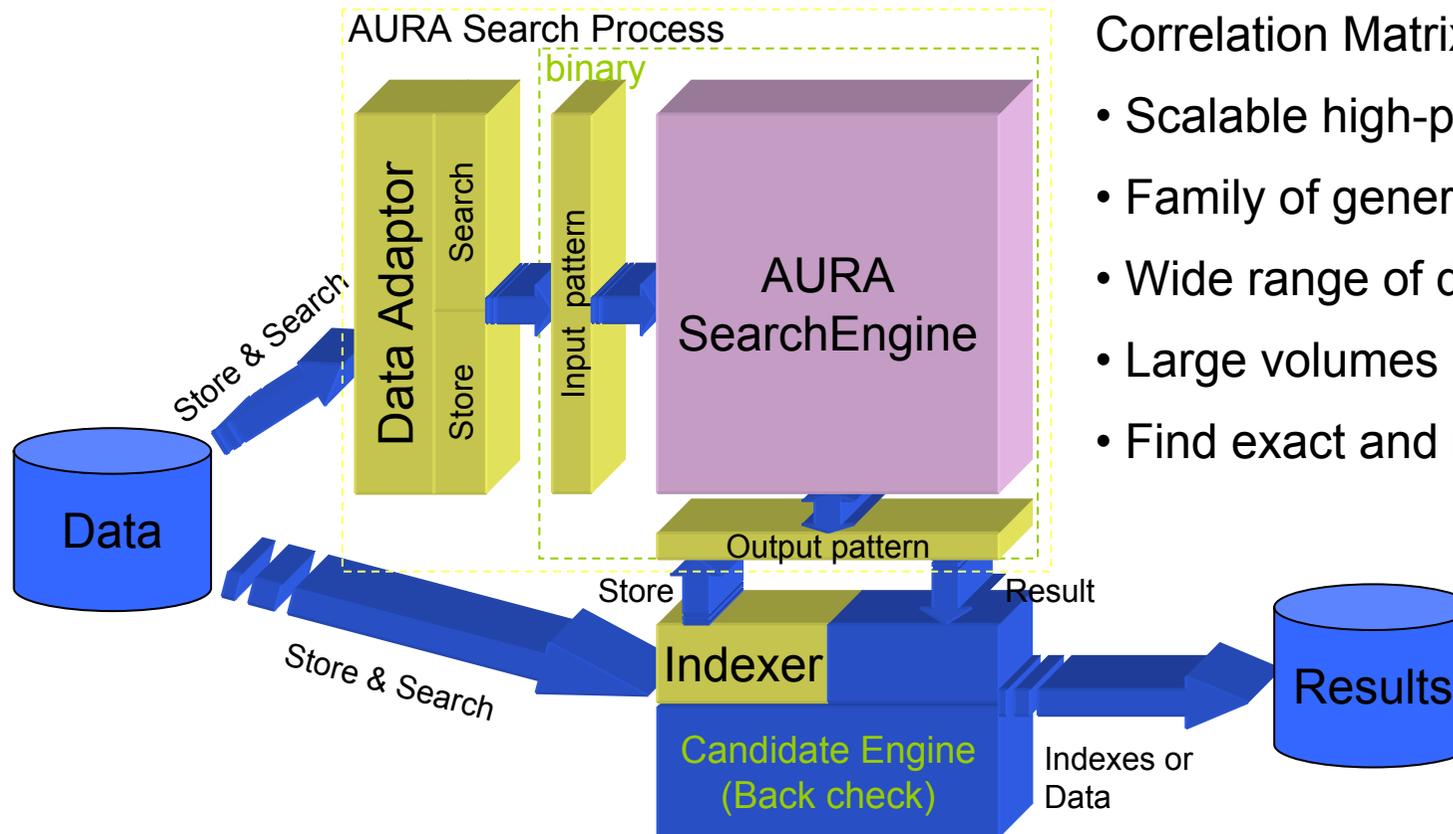
Sources:  Future Segment  Library Pattern  Draw Pad

Threshold: 60

Buttons: Find, Add, Delete, Import, OK

Ready

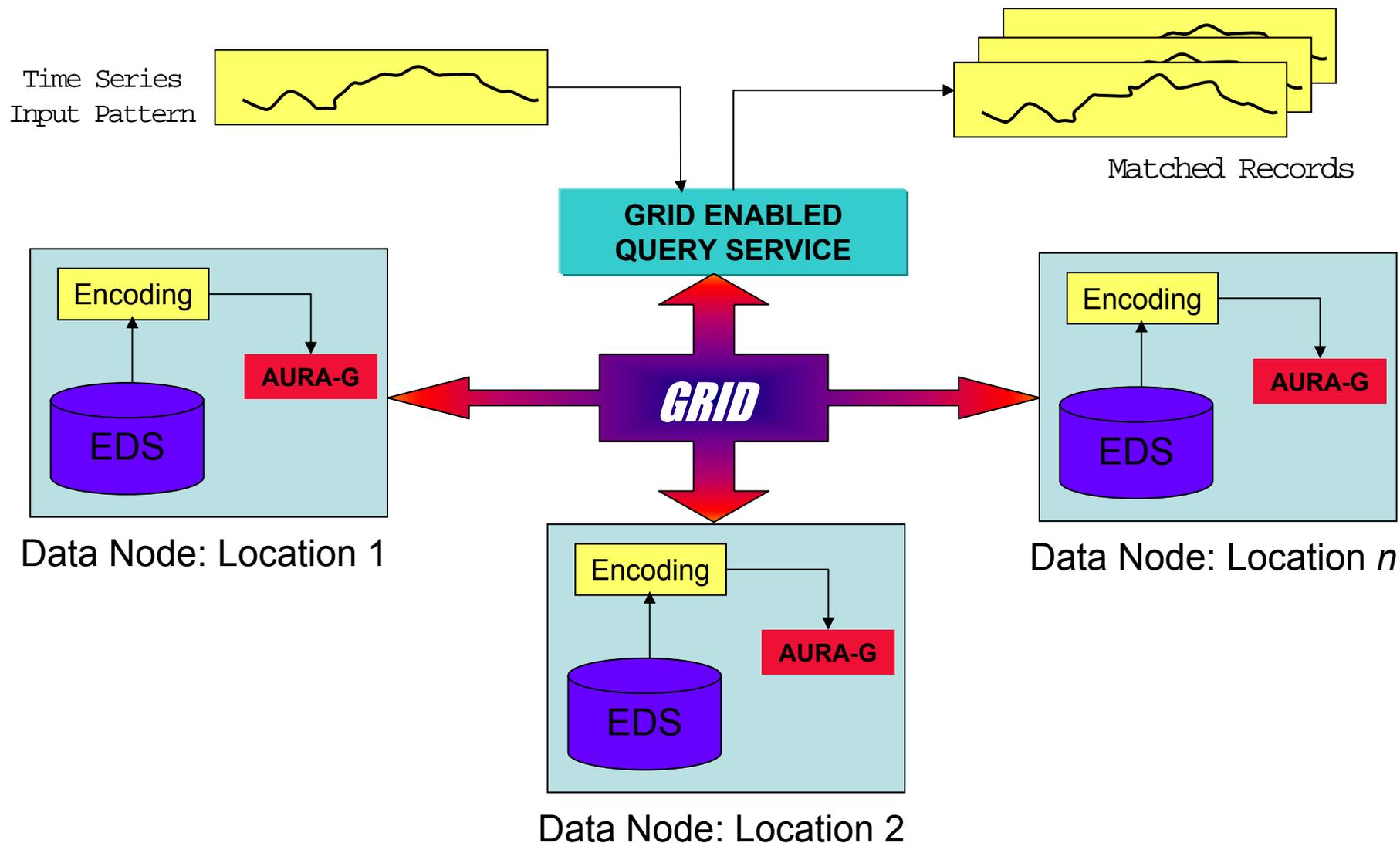
# AURA Technology



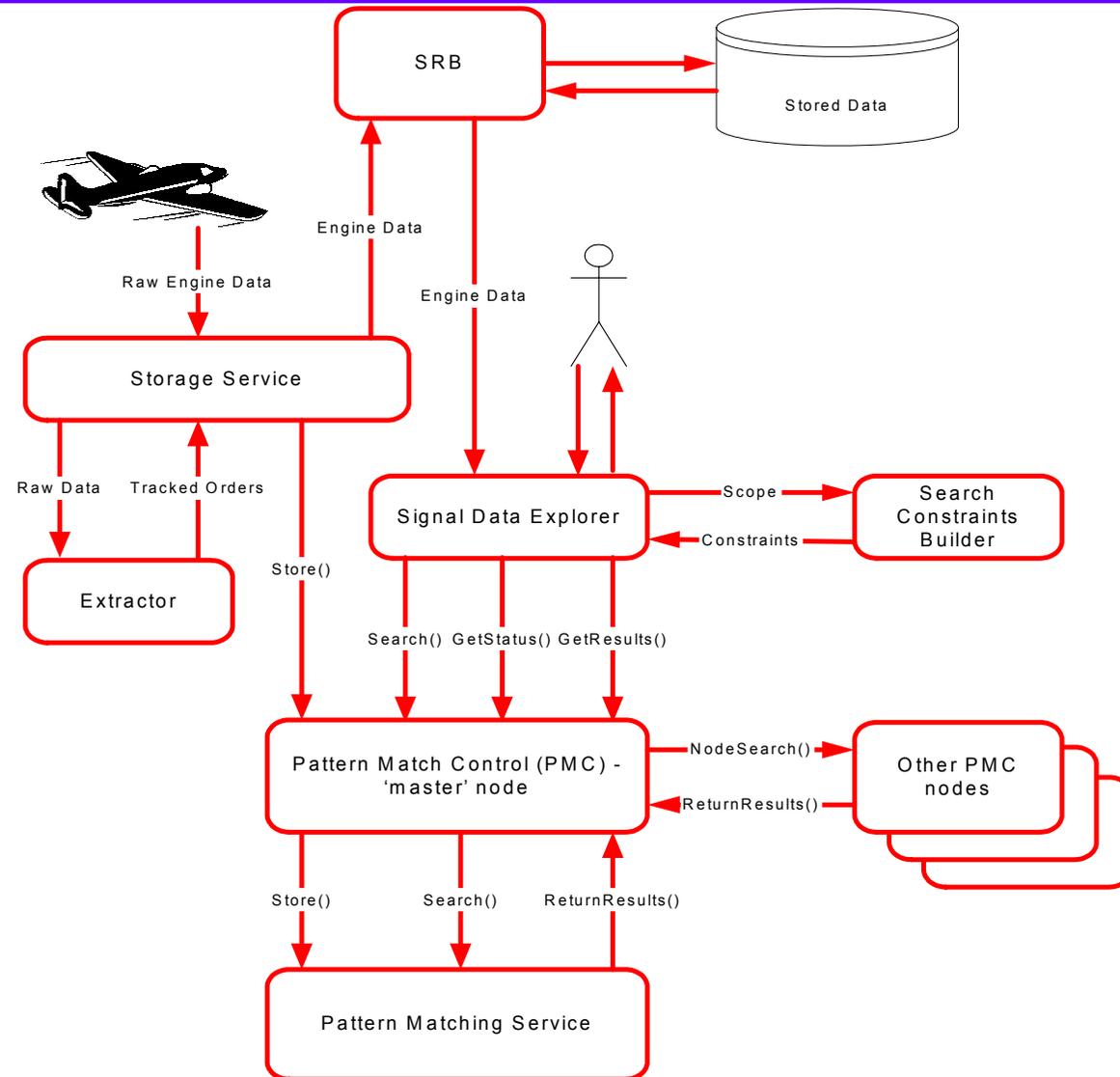
Correlation Matrix Memory (CMM).

- Scalable high-performance.
- Family of generic techniques.
- Wide range of data types.
- Large volumes of data.
- Find exact and near-matches.

# AURA Grid Deployment



# Structure



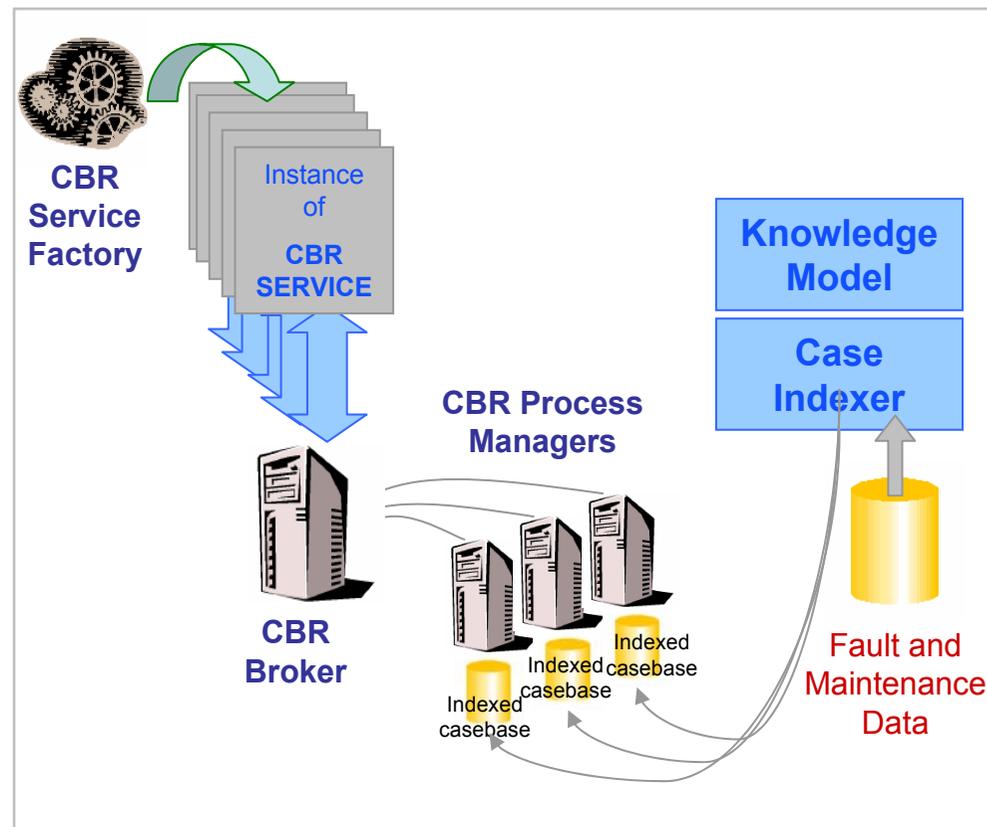
# Case Based Reasoning

CBR service is provided via a Grid service interface to a commercial CBR package;

A *Service Factory* supports the creation of multiple CBR instances

- Permits many CBR processes to be executed in parallel from a single service access point

CBR provides decision support for fault ranking and workflow advice;





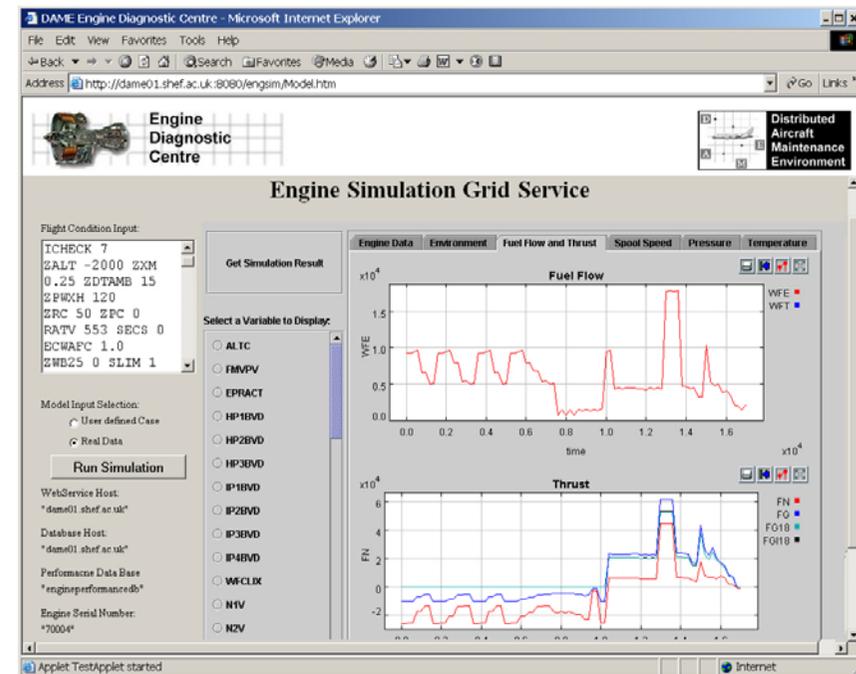
# Engine Model Service



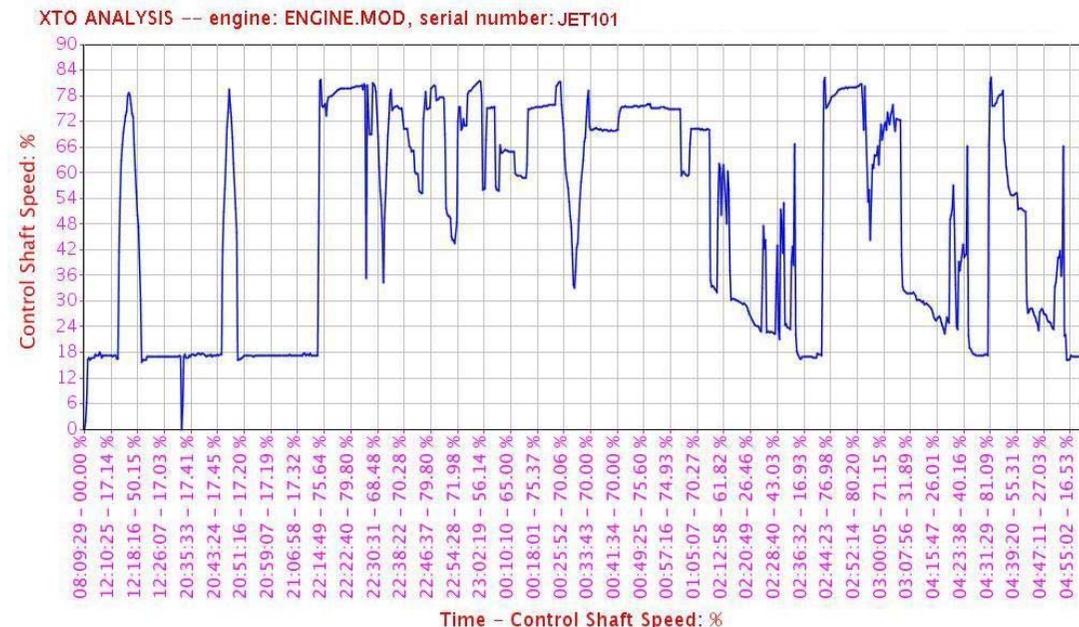
GSI enabled engine performance simulation for different flight operational conditions and requirements, e.g. Idle, Take-off, Climb

The Factory Service can generate a group of engine simulation instances for different client requirements.

Both Transport Level and Message Level Security are implemented to protect the secure sensitive engine model and user data.

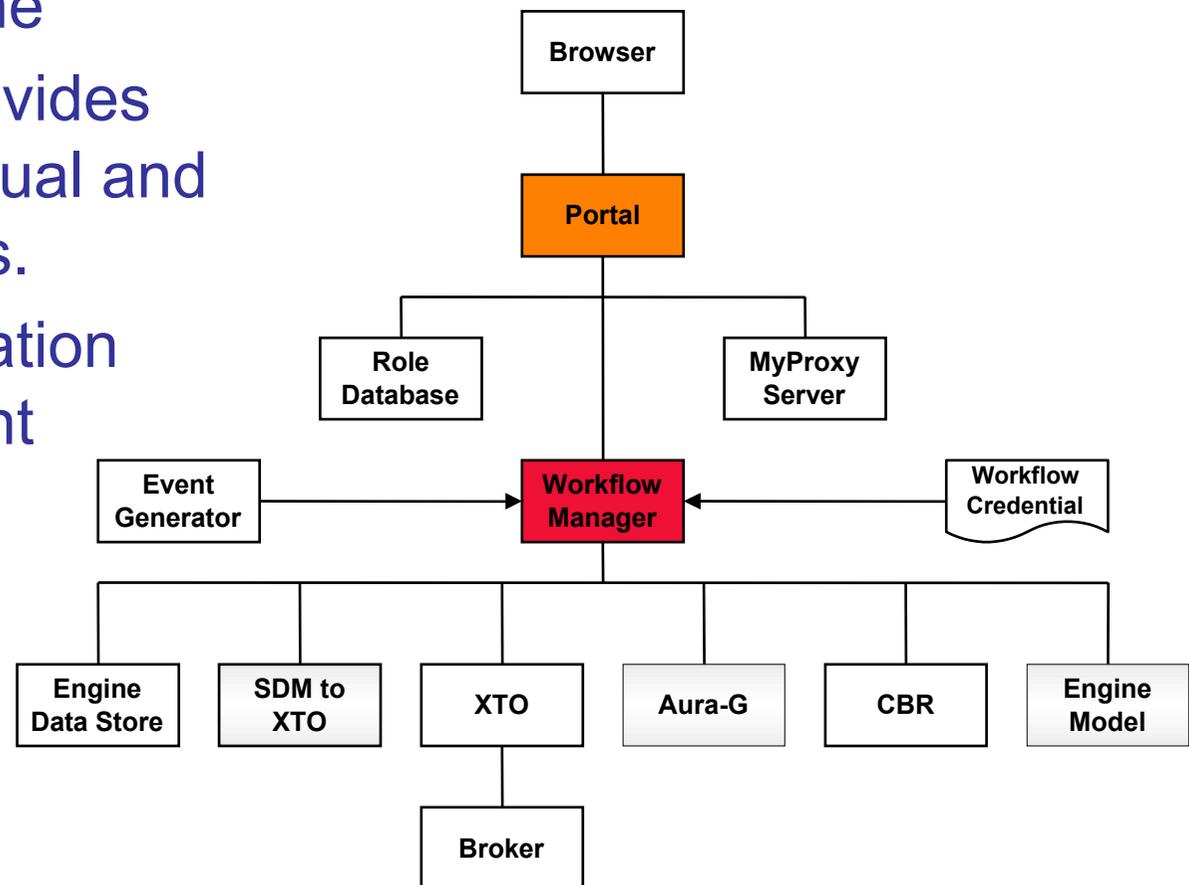


- Grid based deployment of the vibration analysis algorithms:
- Provides:
  - Opportunity for finer grain analysis;
  - More powerful algorithms;
  - Testing environment for development of new algorithms;



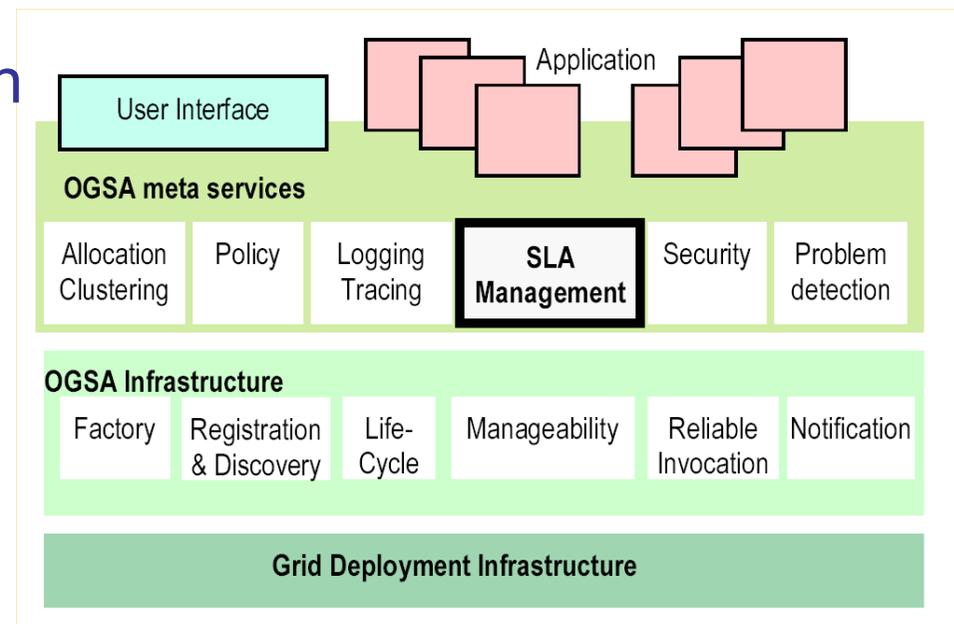
# Workflow Engine

- Services are managed at the portal via a Workflow Engine
- Workflow Engine provides management of manual and automated workflows.
- Also handles certification and role management



# Brokering and SLA's

- Brokerage system is used for job allocation on available Grid resource
- Due to commercial application domain, broker should also demonstrate capability to manage QoS issues, and specifically Service Level Agreements (SLA's)
- Integrates with GGF Grid Economic Architecture





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# Dependability issues

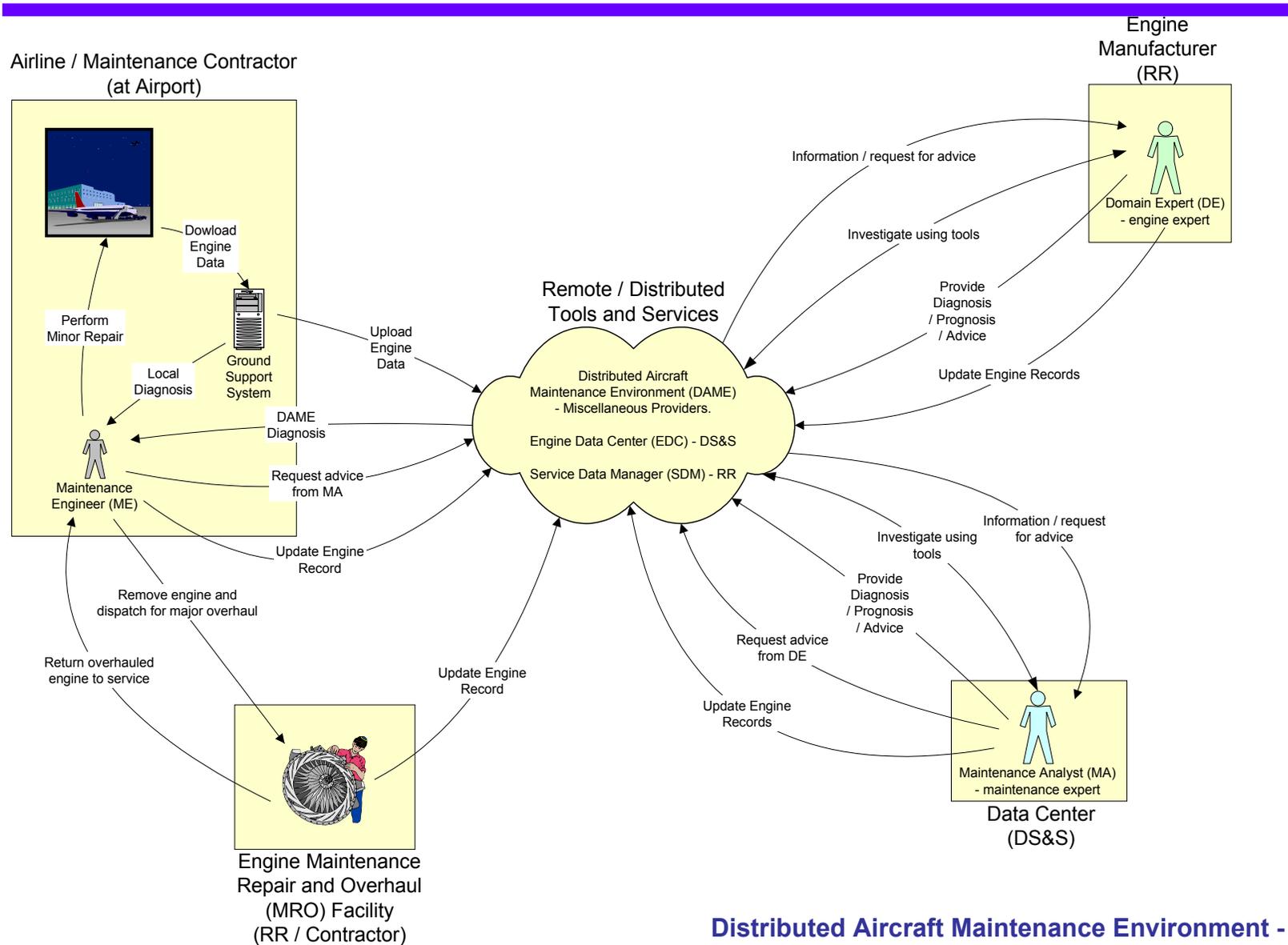


# Dependability Issues



- Contribute to the GRID community dependability and security studies, where possible.
- Provide dependability and security analysis to support the ultimate deployment of DAME as a working engine diagnosis environment.
- If possible, provide a basis (identify good practices) for dependability and security analysis for the deployment of DAME as a working diagnosis environment for other domains e.g. medical.
- Dependability analysis has meant need for business process analysis, asset identification, risk identification.

# Dependability Issues, cont





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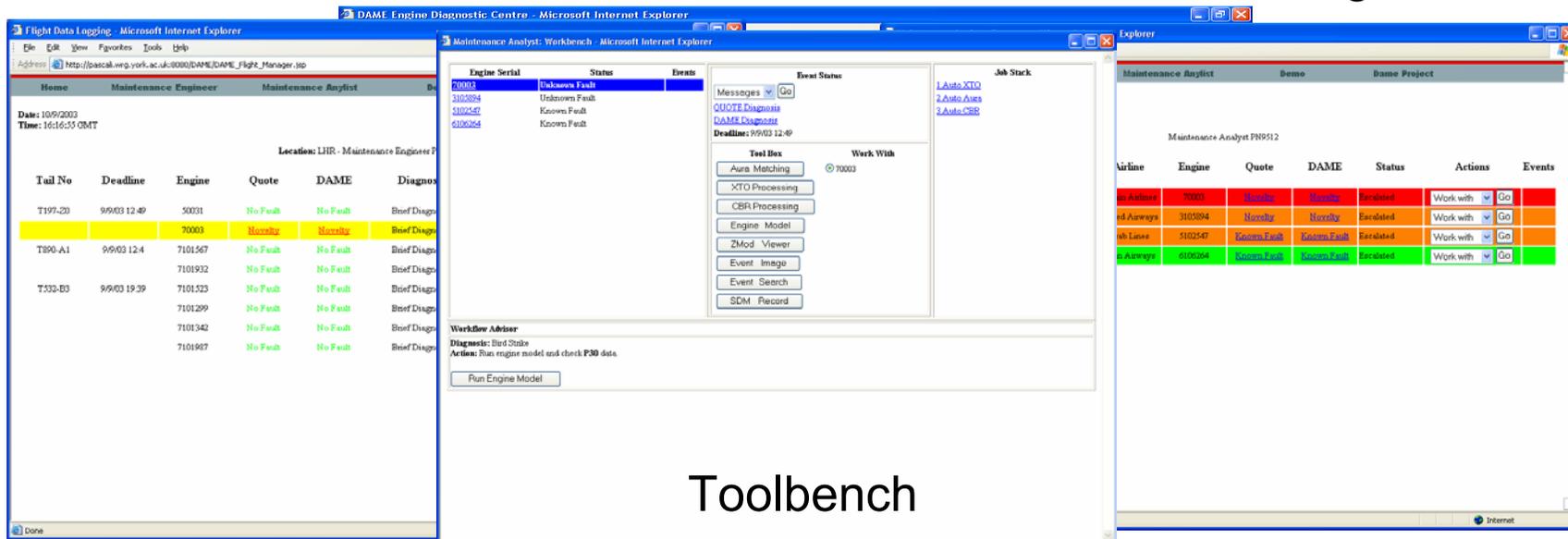
# DAME demonstrator

## Fully operational system on the WRG

- Demonstrated the basic system architecture and main services

Maintenance Analyst

Maintenance Engineer



The screenshot displays three overlapping web browser windows from the DAME system:

- Flight Data Logging:** Shows flight data for 10/09/2003 at 16:16:55 OMT. A table lists maintenance events with columns for Tail No, Deadline, Engine, Quote, DAME, and Diagnosis.
- Maintenance Analyst Workbench:** Shows a detailed view of engine serial 70003. It includes a table of events (Unknown, Unknown, Known, Known faults), a tool box with buttons like 'Auto Matching', 'XTD Processing', 'CBR Processing', 'Engine Model', 'ZMod Viewer', 'Event Image', 'Event Search', and 'SDM Record'. A workflow adviser section is also visible.
- Explorer:** Shows a 'Maintenance Analyst' project for PN9512. It contains a table with columns for Airline, Engine, Quote, DAME, Status, Actions, and Events. The table lists several engines with their respective statuses and actions.

**Toolbench**



Distributed Aircraft  
Maintenance Environment  
DAME

# Demonstrator - SDE



DAME Engine Data Explorer

File Edit View Preferences Tools Help

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Sources:  Future Segment  Library Pattern  Draw Pad

Threshold: 60

Buttons: Find, Add, Delete, Import, OK

Ready



# Demonstrator - CBR



DAME Engine Diagnostic Centre - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Refresh Home Search Favorites History Mail Print Edit

Address <http://143.167.54.101:8888/Projects/damephase2/DAMEDiagnosticCentre/>

 **Engine Diagnostic Centre**

 **Distributed Aircraft Maintenance Environment DAME**

**Home Case-Based Reasoning Novelty Analysis Engine Diagnostic Service Dame Project**

The following matching cases were found...

Case ID: <b>3</b> Date: <b>2002-04-15 19:00:00</b> [95 % confidence] Case Title : <b>shaft bearing</b> Proposed Diagnosis Action 1 : <b>Check debris analysis for lost metal</b> Proposed Diagnosis Action 2 : <b>Use PCD to isolate faulty bearing/ball</b> Proposed Solution : <b>Maintenance action SB-143-A</b>	 <a href="#">View Case</a>
<a href="#">Service Data</a> <a href="#">Maintenance Report</a>	
Case ID: <b>1</b> Date: <b>2002-03-01 14:50:00</b> [20 % confidence] Case Title : <b>shaft imbalance</b> Proposed Diagnosis Action 1 : <b>Check primary shaft balance</b> Proposed Diagnosis Action 2 : Proposed Solution : <b>Maintenance action PS-101-B</b>	 <a href="#">View Case</a>
<a href="#">Service Data</a> <a href="#">Maintenance Report</a>	
Case ID: <b>2</b> Date: <b>2002-04-09 11:02:00</b> [10 % confidence] Case Title : <b>fan blade</b> Proposed Diagnosis Action 1 : <b>Inspect fan blades</b> Proposed Diagnosis Action 2 : <b>Perform boroscope inspection on LP compressor</b> Proposed Solution : <b>Replace damaged LP blades</b>	 <a href="#">View Case</a>
<a href="#">Service Data</a> <a href="#">Maintenance Report</a>	

Done Internet



# Demonstrator – Engine model



**Engine Diagnostic Centre**

### Engine Simulation Grid Service

Flight Condition Input:

- ICHECK 7
- ZALT -2000 ZXM
- 0.25 ZDTAMB 15
- ZPMXH 120
- ZRC 50 ZPC 0
- RATV 553 SECS 0
- ECWAPC 1.0
- ZWB25 0 SLIM 1

Model Input Selection:

- User defined Case
- Real Data

**Run Simulation**

WebService Host: "dame01.shef.ac.uk"

Database Host: "dame01.shef.ac.uk"

Performance Data Base: "engineperformancedb"

Engine Serial Number: "70004"

Select a Variable to Display:

- ALTC
- FMVPV
- EPRACT
- HP1BVD
- HP2BVD
- HP3BVD
- IP1BVD
- IP2BVD
- IP3BVD
- IP4BVD
- WFCLIX
- N1V
- N2V

**Engine Data** | Environment | Fuel Flow and Thrust | Spool Speed | Pressure | Temperature

**Fuel Flow**

Y-axis:  $\times 10^4$  WFE (0.0 to 1.5)

X-axis: time (0.0 to 1.6)

**Thrust**

Y-axis:  $\times 10^4$  FN (-2 to 6)

X-axis: time (0.0 to 1.6)

Legend for Thrust: FN (red), FG (blue), FG18 (green), FG18 (black)

Legend for Fuel Flow: WFE (red), WFT (blue)

Applet: TestApplet started

# Demonstrator – XTO advisor

XTO ANALYSIS -- engine: ENGINE.MOD, serial number: JET101





# Typical work flow



- Data event identified on the engine
- Aircraft lands – data off loaded
- Automatic work flow searches previous history
- Engineer presented with results – decided on action
- Escalated to domain expert – detailed analysis
- Airline contacted to OK maintenance
- Maintenance scheduled
- Maintenance carried out
- Engine Data Centre updated with maintenance under taken



## Future work



- Completion of the in-lab demonstrator.
- Move to deploy on test bed within Rolls-Royce.
- Then to implement for flight data.
  
- Jim Austin, Tom Jackson, Martyn Fletcher, Mark Jessop, Peter Cowley, Peter Lobner, **Predictive Maintenance: Distributed Aircraft Engine Diagnostics**, *The Grid: Blueprint for a New Computing Infrastructure*, Edited by Ian Foster & Carl Kesselman, Chapter 5.



[www.cs.york.ac.uk/dame](http://www.cs.york.ac.uk/dame)

Paul Anuzis

Georges Honoré

Haydn Thompson

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Alison McKay

Rob Davis

Graham Hesketh

Sarfraz Nadeem

Martyn Fletcher

Jack Crawford

Paul Hayton

Tom Jackson

Charlie Dibsedale

Lionel Tarassenko

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Thanks!