



Distributed Aircraft
Maintenance Environment
DAME

DAME: Distributed Engine Health Monitoring – Data Architecture for the Grid

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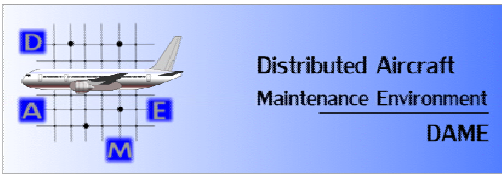
Project Partners



- EPSRC Funded, £3.2 Million, 3 years, commenced Jan 2002.
- UK pilot project for e-Science (£220 million programme)
- 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

DAME Objectives

- Building a demonstration system as proof of concept for Grid technology in the aerospace diagnostic domain.
- Three primary Grid challenges:
 - Management of large, distributed and heterogeneous data repositories;
 - Rapid data mining and analysis of fault data;
 - Information management and data fusion for diagnosis/prognosis applications;
- 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)

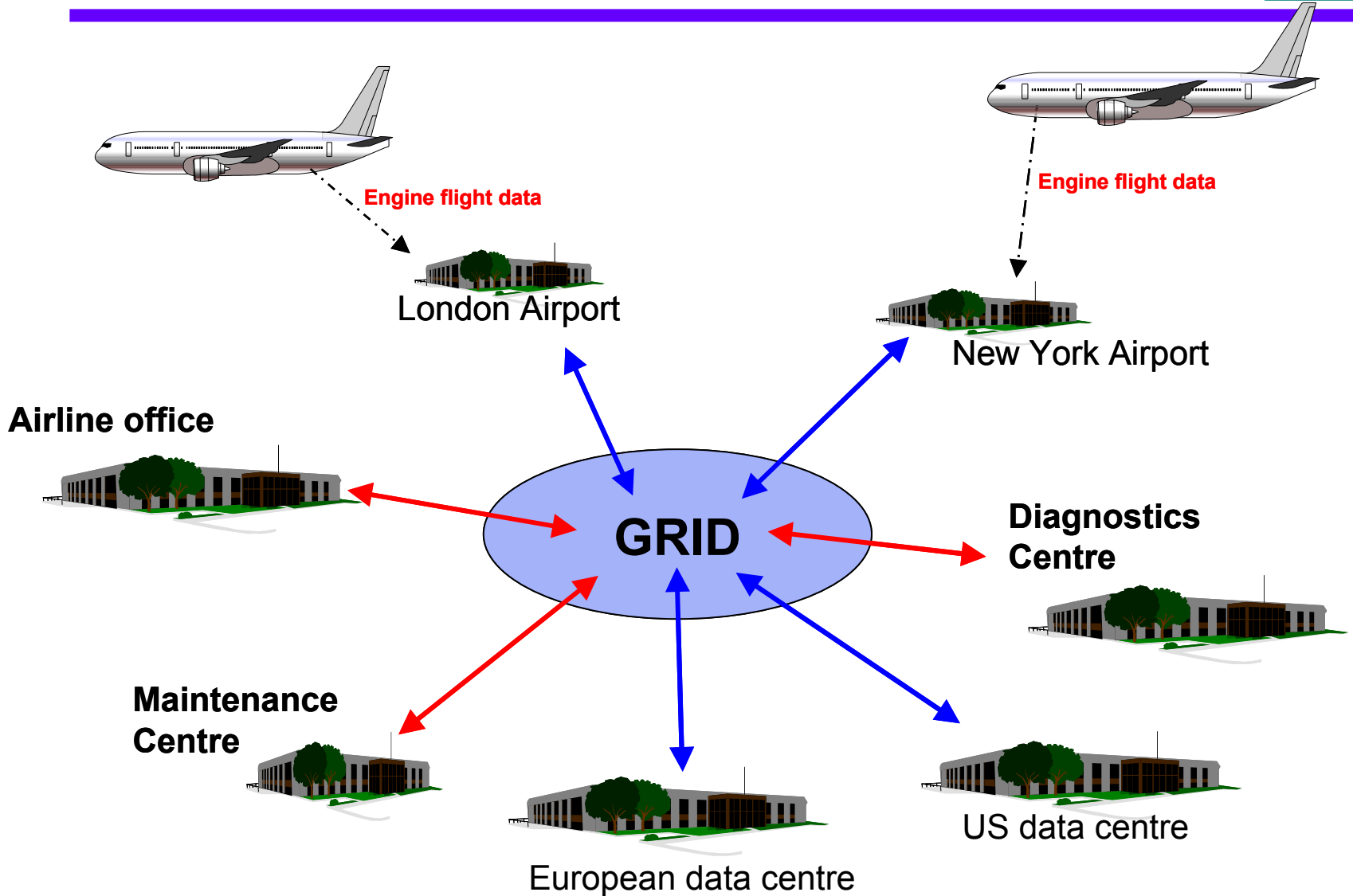


Business & Technical Drivers



- As research partners, RR and DS&S have provided a potential business scenario that has been used to drive technical developments in several areas:
 - Virtual Organisations (VO)
 - Supporting multiple, distributed stakeholders within the business process
 - Large scale distributed data management and mining
 - How to maximise the commercial benefit of data derived from health monitoring systems
 - Secure, distributed data
 - How to protect assets and control access to data assets within a VO
 - Quality of Service
 - How to guarantee levels of service for remote services and systems.

Operational Scenario



How Big is the Data Problem?

An example scenario:

- Heathrow capped at 36 landings per hour.
- If half have 4 engines and half have 2, average aircraft carries 3 engines.
- Each engine generates around 1GB of data per flight.
- $36 \times 3 \times 1 = 108\text{GB}$ raw engine data per hour.
- Factor in the working day and the rest of the world...
- ...Terabytes and up!



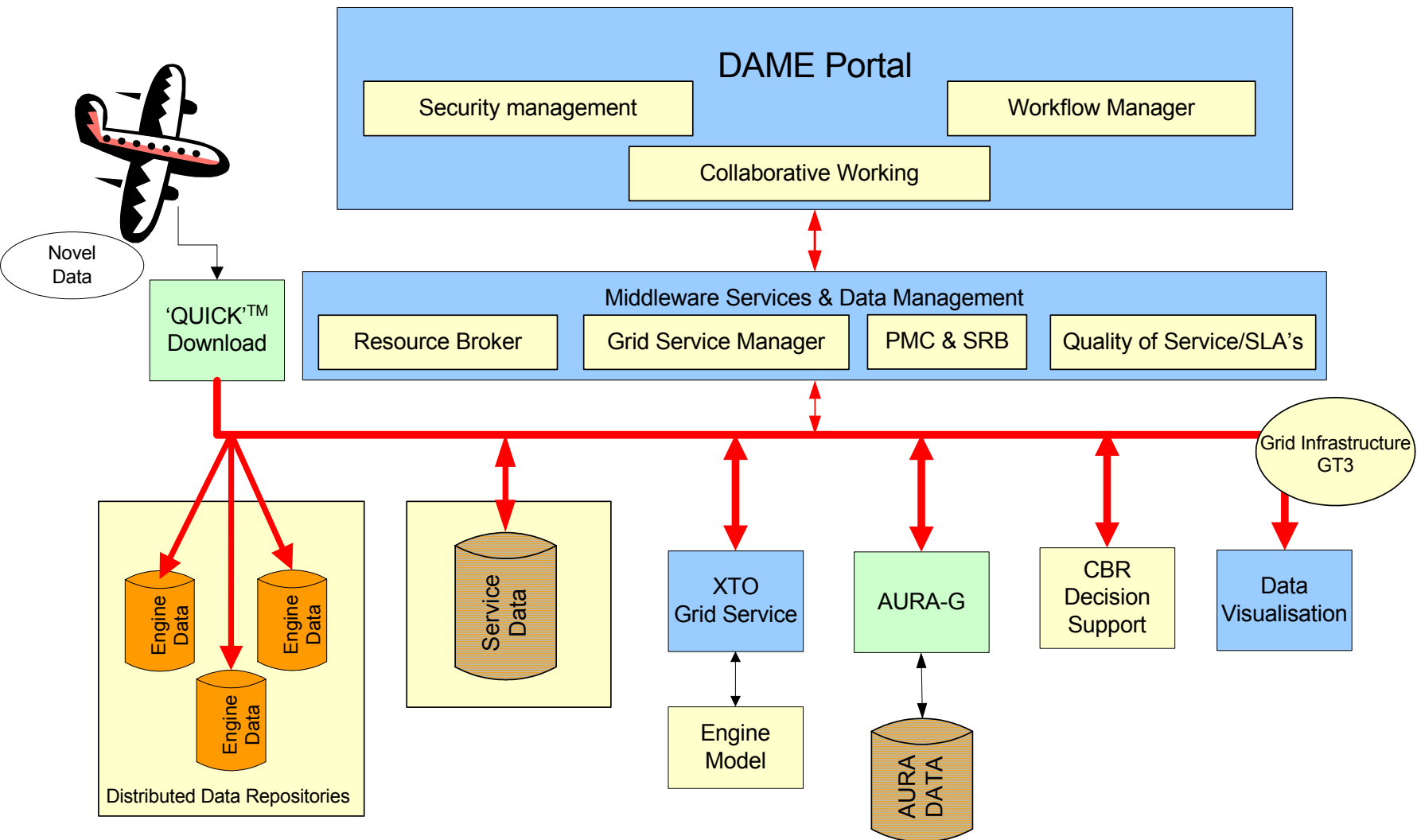
Demonstrator Objectives



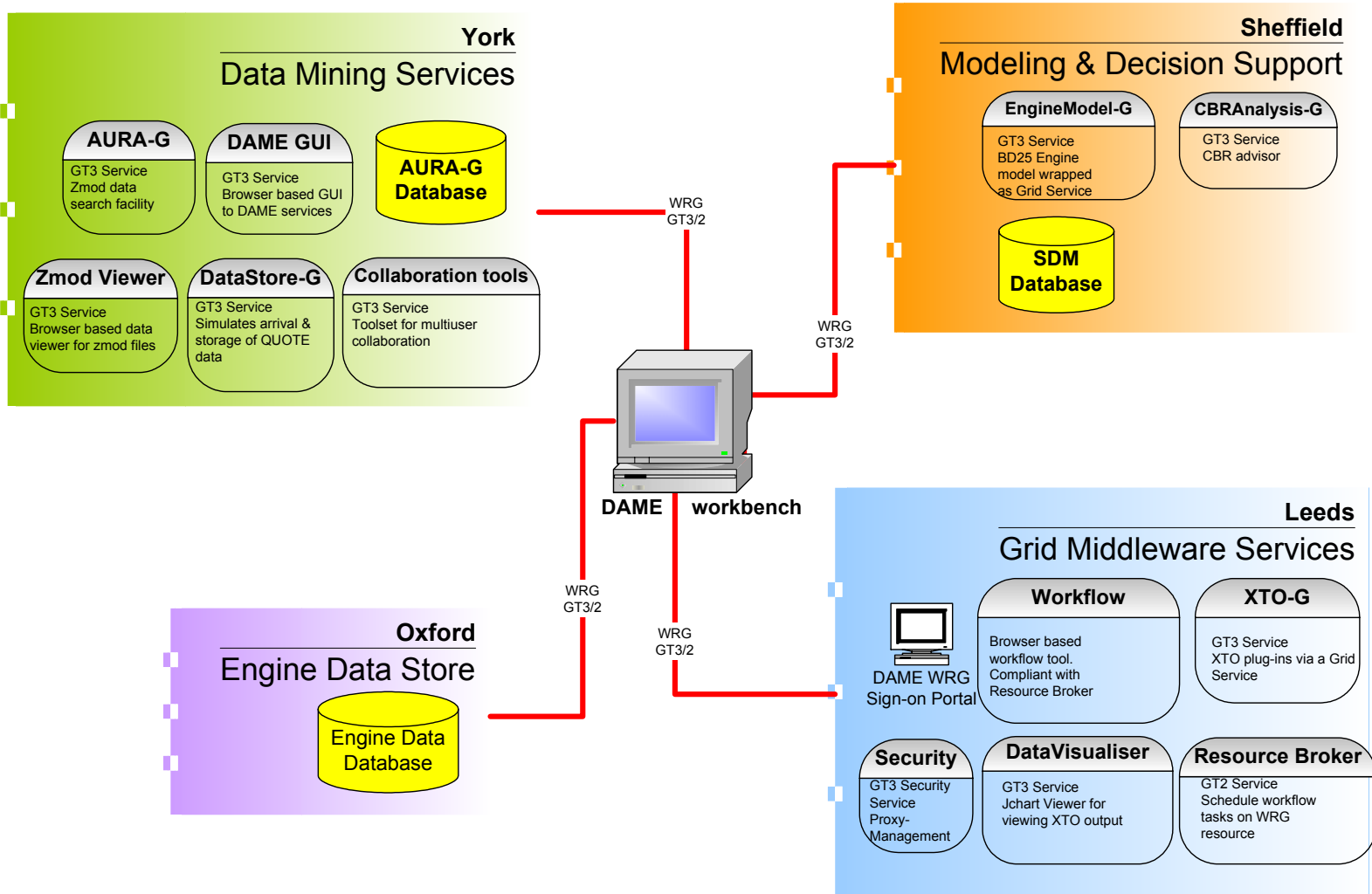
The DAME demonstration system provides a diagnosis workbench (portal) which brings together a suite of analysis services via Grid technology;

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

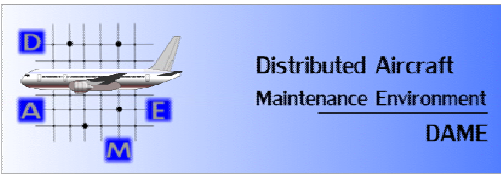
DAME Functional Overview



White Rose Grid Distribution



- Objectives have been to develop a data mining service to search fleet archives of QUICK engine data within operational time constraints.
 - To support diagnosis and prognosis activities
 - To support long term fleet predictive maintenance
 - Business assumption is that data is archived remotely
- Two tools have been developed:
 - AURA-G: Grid enabled signal search engine;
 - Signal Data Explorer: Interactive search GUI for signal data
- These tools are generic to any pattern matching domain, but have been tuned to RR & DS&S requirements for DAME.



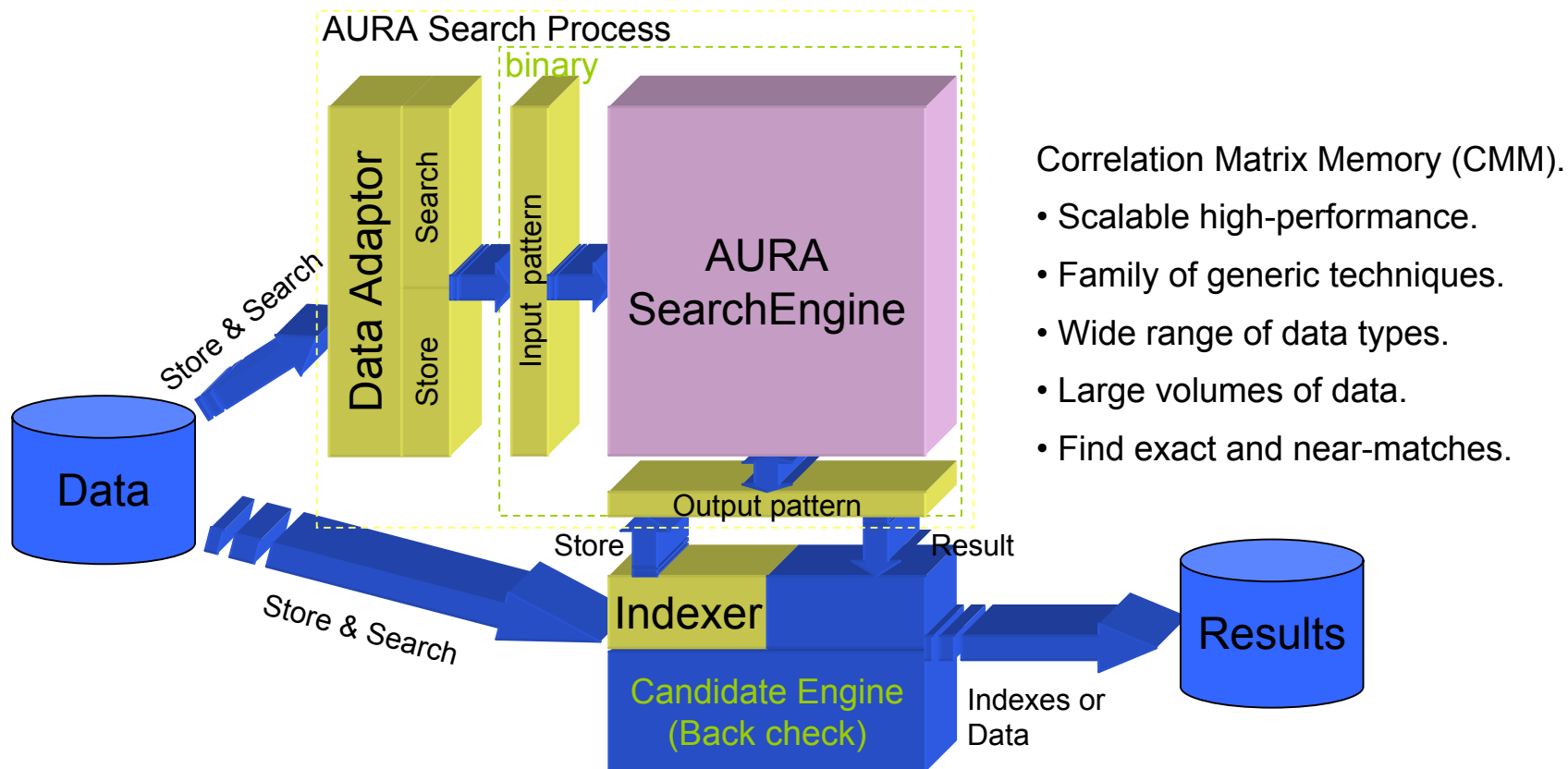
AURA-G Service & PMC



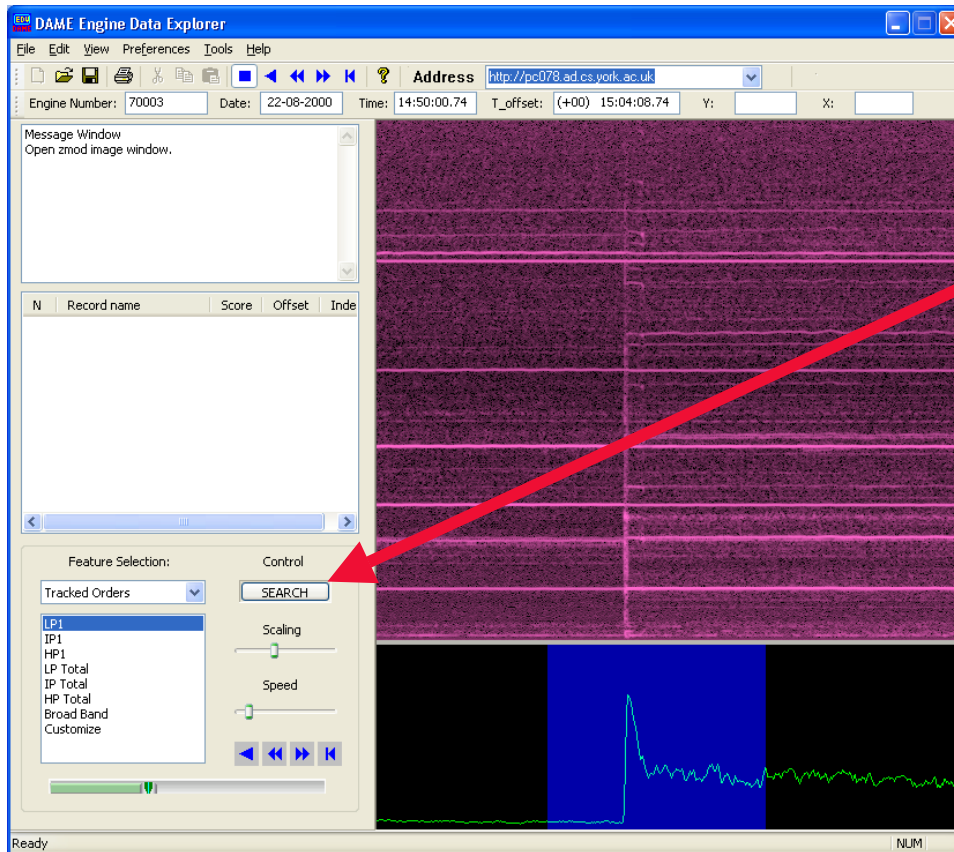
- AURA is a highly scalable, binary associate memory technology, developed for advanced pattern matching applications.
- DAME has developed a distributed Grid enabled version of this technology; matches commercial challenges of data growth and data distribution.
- Provides capability to mine huge volumes (Terabytes) of complex signal data with sub second response times.
- AURA-G is managed by a DAME middleware service called Pattern Match Controller:
 - Provides mechanisms for distributing and managing search queries
- A virtual data archiving system, Storage Request Broker(SRB) provides the middleware for data cataloguing and archiving.

AURA Integration & Deployment

- AURA is a collection of processes; data adaptors, search-engine and back-check. It wraps around an **existing data storage system**;



- Complex time-series pattern matching process driven from a visualisation front end.

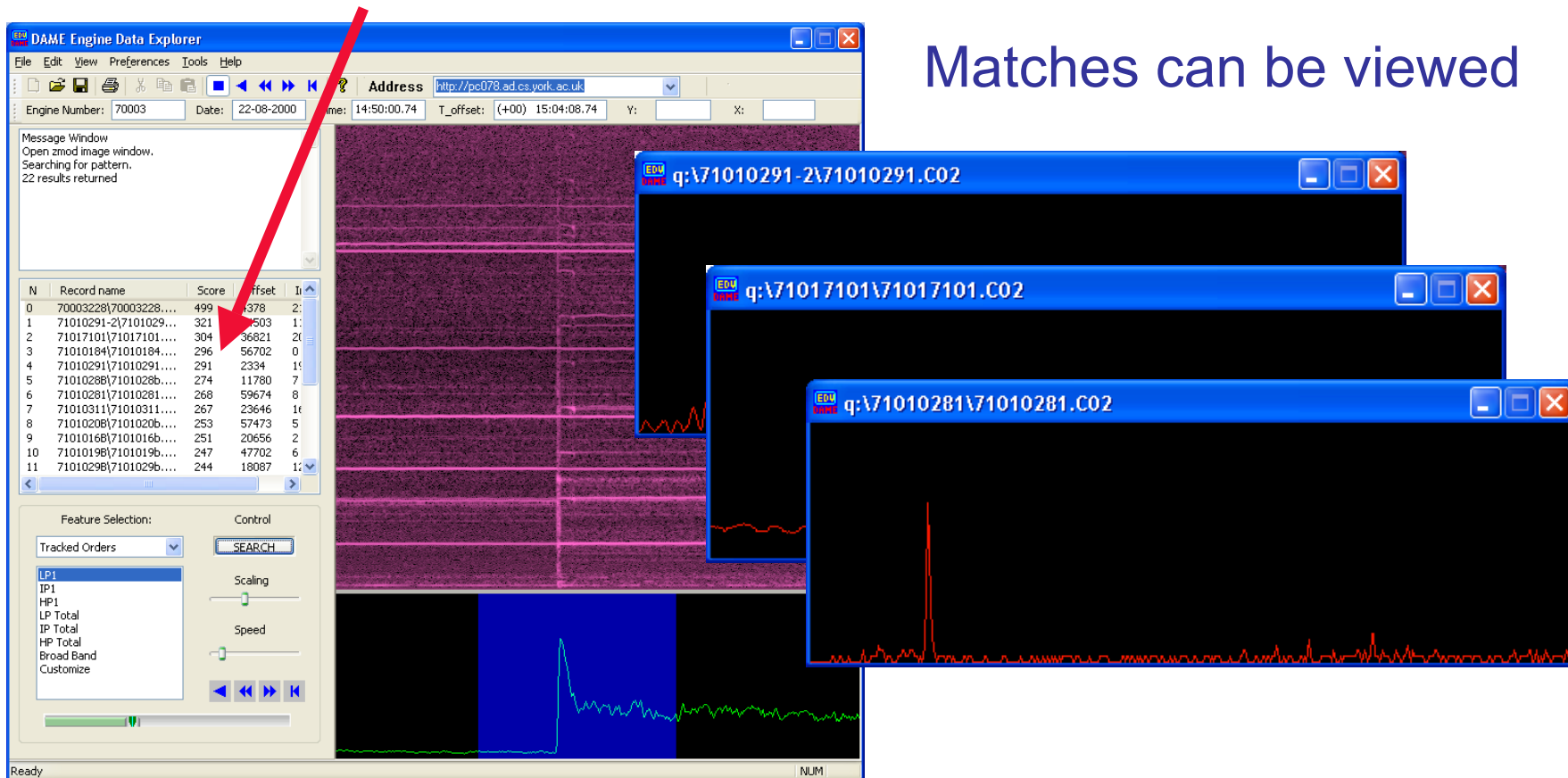


A search is launched across the fleet data archives using the Grid enabled AURA search engine

Engineer selects region of interest

- All matched pattern records are retrieved from the fleet archives and ranked according to similarity

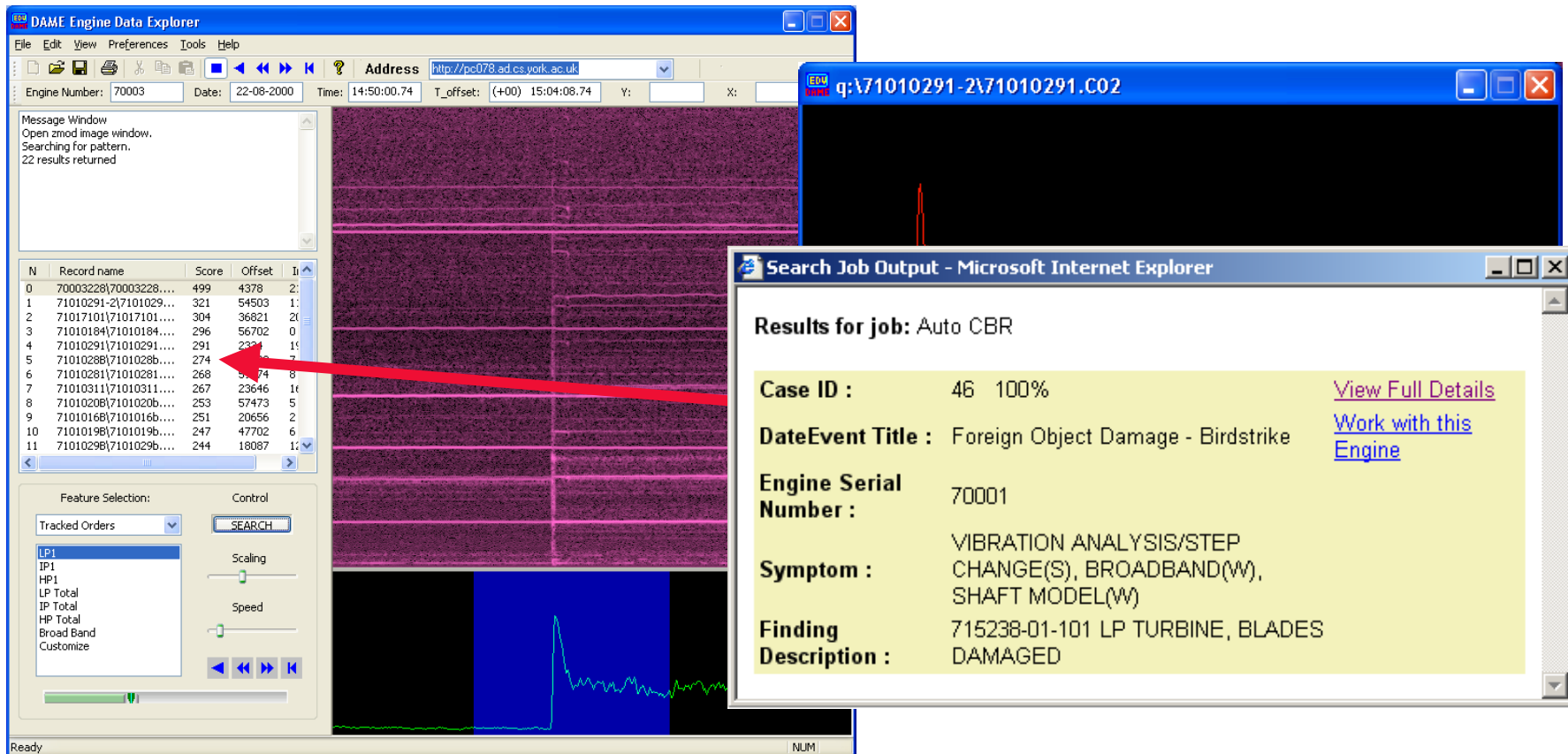
Matches can be viewed



The screenshot shows the DAME Engine Data Explorer interface. A red arrow points from the search results table to a large engine data visualization window. Three smaller windows are overlaid, showing zoomed-in views of specific engine data patterns.

N	Record name	Score	Offset	...
0	70003228\70003228....	499	378	2:
1	71010291-2\71010291....	321	3503	1:
2	71017101\71017101....	304	36821	2:
3	71010184\71010184....	296	56702	0:
4	71010291\71010291....	291	2334	1:
5	71010288\71010288....	274	11780	7:
6	71010281\71010281....	268	59674	8:
7	71010311\71010311....	267	23646	1:
8	71010208\71010208....	253	57473	5:
9	71010168\71010168....	251	20656	2:
10	71010198\71010198....	247	47702	6:
11	71010298\71010298....	244	18087	1:

- The case history associated with any meaningful signature can be recalled from the fleet maintenance logs



The screenshot displays the DAME Engine Data Explorer interface. The main window shows a search results table with columns for Record name, Score, and Offset. A red arrow points from the table to a detailed search job output window.

N	Record name	Score	Offset	I
0	70003228\70003228....	499	4378	2:
1	71010291-2\71010291....	321	54503	1:
2	71017101\71017101....	304	36821	2:
3	71010184\71010184....	296	56702	0:
4	71010291\71010291....	291	2371	1:
5	71010288\71010288....	274		
6	71010281\71010281....	268	5774	8:
7	71010311\71010311....	267	23646	1:
8	71010208\71010208....	253	57473	5:
9	71010168\71010168....	251	20656	2:
10	71010198\71010198....	247	47702	6:
11	71010298\71010298....	244	18087	1:

Search Job Output - Microsoft Internet Explorer

Results for job: Auto CBR

Case ID : 46 100% [View Full Details](#)

DateEvent Title : Foreign Object Damage - Birdstrike [Work with this Engine](#)

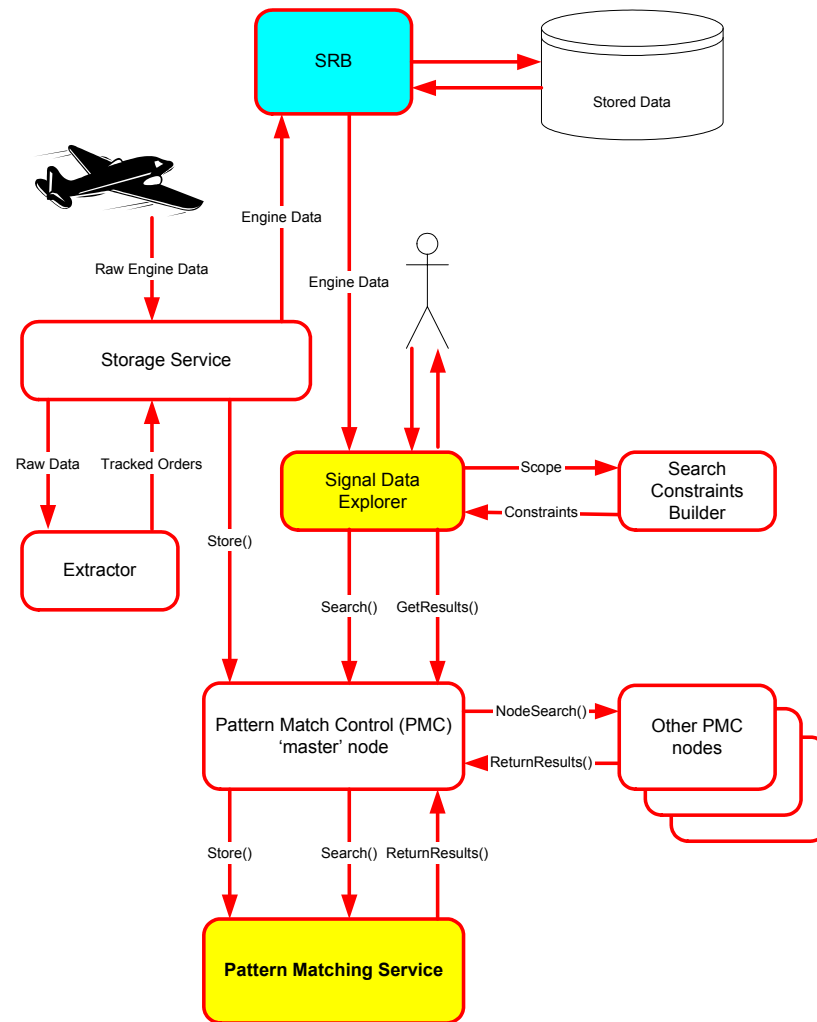
Engine Serial Number : 70001

Symptom : VIBRATION ANALYSIS/STEP CHANGE(S), BROADBAND(W), SHAFT MODEL(W)

Finding Description : 715238-01-101 LP TURBINE, BLADES DAMAGED

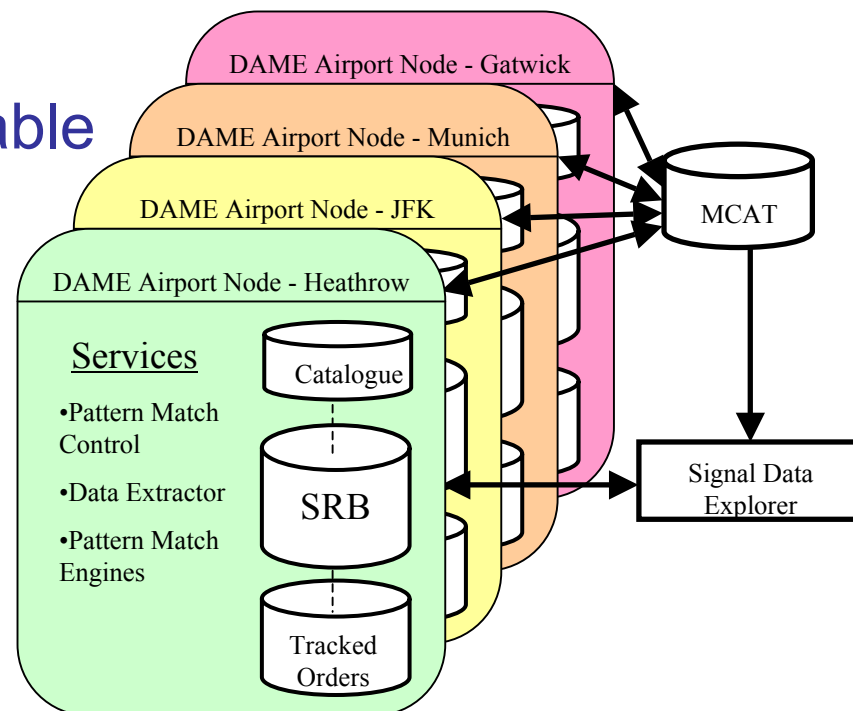
Pattern match Control

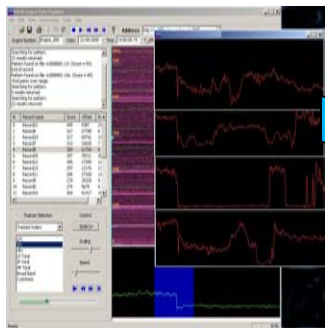
- The SDE interfaces to the PMC middleware
- GT3.0 enabled service components;
- PMC provides:
 - Distributed search
 - Interface to data archive system (SRB or other)
 - Scalability
 - Robustness



PMC cont

- PMC architecture has been developed on business premise of remote data.
- E.g. Airports act as data repositories for Engine health data
- SRB provides hugely scalable virtual catalogue & index system





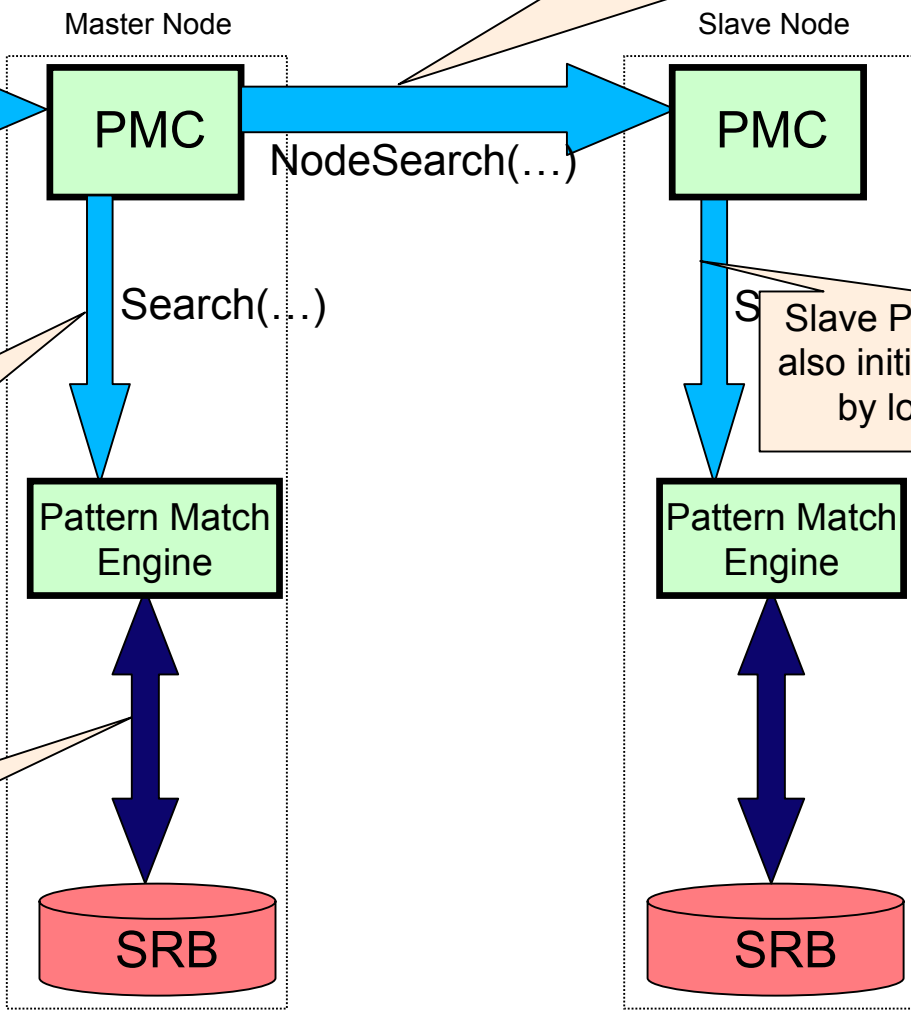
Signal Data Explorer
(Client Application)

The node receiving the request becomes the 'master' for a search.

The master PMC service replicates the search request to all other nodes.

In addition, the master PMC service initiates a search by a Pattern Matching Engine at that node.

Pattern Match Engines request and stream data from SRB.



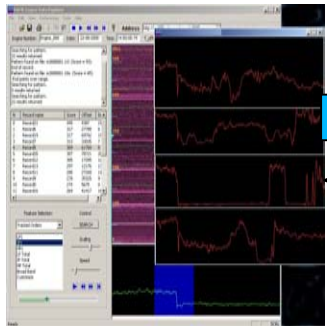
Heathrow

Gatwick

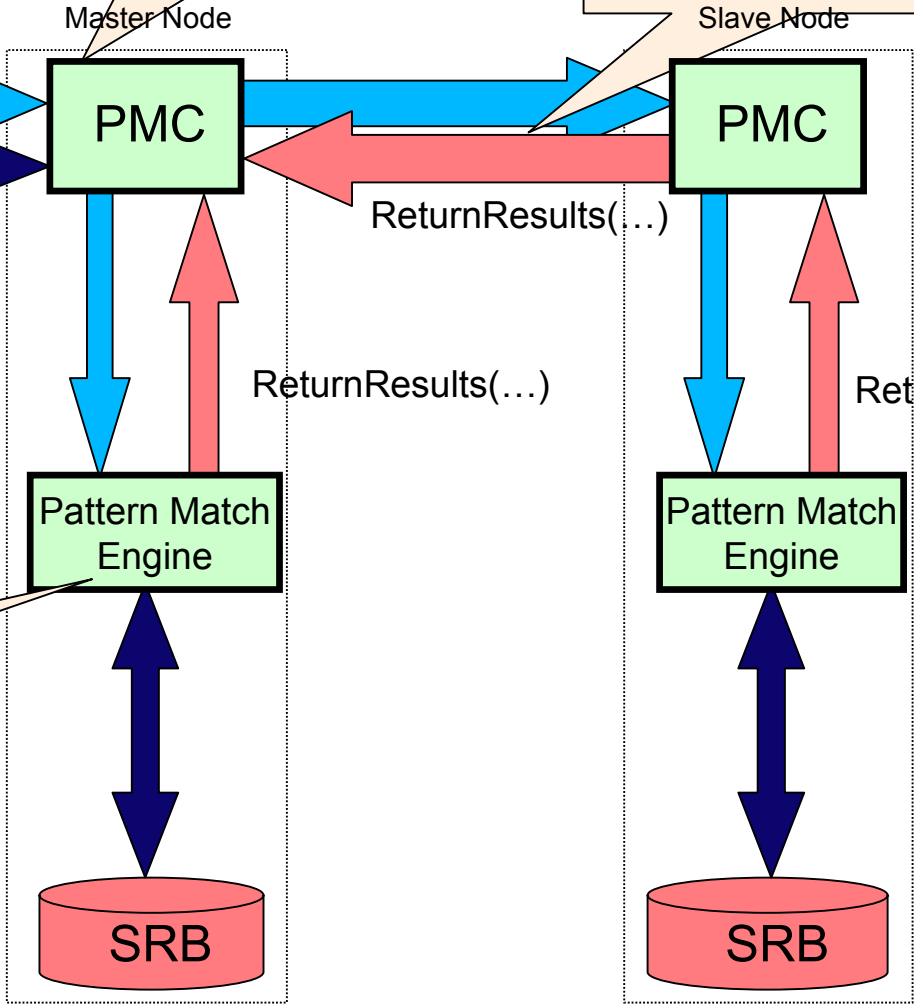
The client can request the current result set at any time.

The master PMC combines all the results received into a single set.

Slave PMCs deliver their results to the master PMC service.



Signal Data Explorer (Client Application)



After searching, Pattern Matching Engines return results to the calling PMC service.

GetResults(...)

ReturnResults(...)

ReturnResults(...)

ReturnResults(...)

Heathrow

Gatwick

Decision Support tools

- Objectives are to maximise use of available data assets to support business processes:
 - Diagnosis & Prognosis
 - Fleet predictive maintenance
 - Workflow management
 - Domain knowledge capture
- Achieved through integration of diverse data assets through Grid enabled Case Based Reasoning tools.
- Grid provides standardised interface to legacy systems and data servers.



CBR Maintenance Analysis in DAME



The screenshot displays the 'Maintenance Analyst: Workbench - Microsoft Internet Explorer' window. It features a table of engine serials and their statuses, a 'Tool Box' with 'CBR Processing' highlighted, and a 'Workflow Advisor' section. A separate window, 'Search Job Output - Microsoft Internet Explorer', shows the results for an 'Auto CBR' job, including details like Case ID, DateEvent Title, Engine Serial Number, Symptom, and Finding Description. A red arrow points from the 'CBR Processing' button in the workbench to the search results window.

Engine Serial	Status	Events
70003	Unknown Fault	
5102547	Known Fault	
3105894	Unknown Fault	
6106264	Known Fault	

Event Status
Messages
[QUOTE Diagnosis](#)
[DAME Diagnosis](#)
Deadline: 12/2/04 13:47

Tool Box

Work With
70003

Job Stack
[1.Auto XTO](#)
[2.Auto Aura](#)
[3.Auto CBR](#)

Workflow Advisor
Diagnosis: Bird Strike
Action: Run engine model and check P30 data.

Search Job Output - Microsoft Internet Explorer
Results for job: Auto CBR

Case ID :	46 100%	View Full Details
DateEvent Title :	Foreign Object Damage - Birdstrike	Work with this Engine
Engine Serial Number :	70001	
Symptom :	VIBRATION ANALYSIS/STEP CHANGE(S), BROADBAND(W), SHAFT MODEL(W)	
Finding Description :	715238-01-101 LP TURBINE, BLADES DAMAGED	

- User driven CBR processing
- Automated CBR processing via Workflow Manager



Summary



- DAME is demonstrating the potential of Grid-based diagnostics for health-monitoring applications;
- Grid paradigm offers:
 - Scalable solutions for management of distributed data
 - Secure access to services and data
 - Role based access and virtual collaboration on fault data
- DAME has shown how data growth problems could potentially be addressed within scope of distributed data assets.