



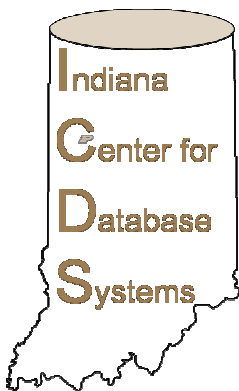
**PURDUE**  
UNIVERSITY



# Knowledge-Projection for Tele-Maintenance

*The Purdue Knowledge Projection Group*

*Joint work with NSWC Crane, Purdue, Indiana University,  
and EG&G*



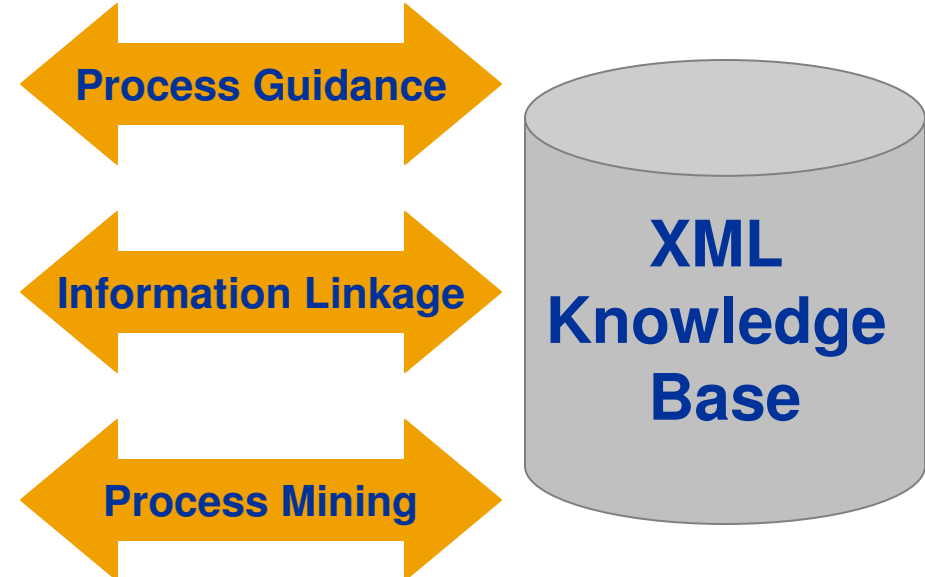
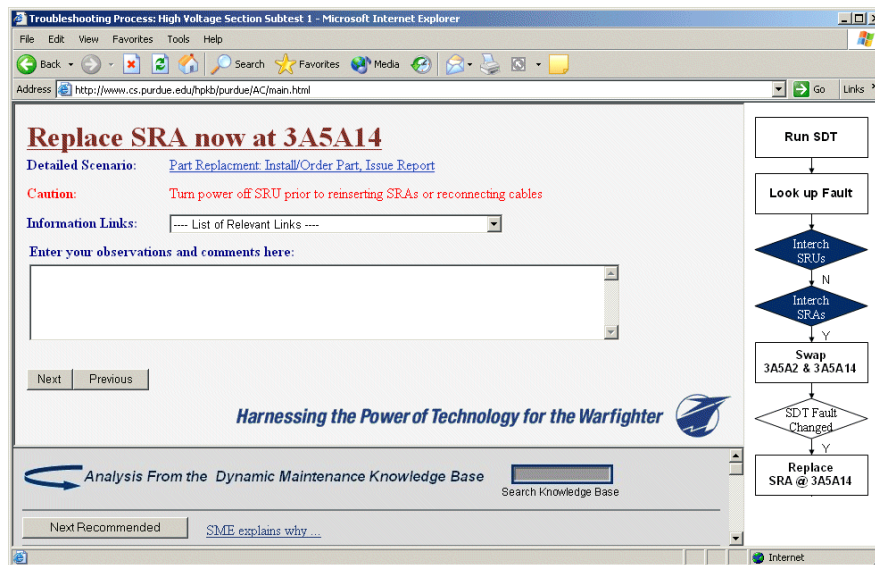
*Harnessing the Power of Technology for the Warfighter*



# Dynamic Maintenance

## The Unified Knowledge Base View

Technology that supports the end-to-end maintenance process with built-in analysis to better understand it



**Example Application for  
Mission Critical Troubleshooting**  
*"all the information the sailor needs,  
exactly when it's needed"*

## Slide 2

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### **RAB6**

suggestion is to change "sailor needs exactly when he needs it" to sailor needs when it is needed" to avoids gender specific phrasing.  
Rose Brenner, 6/10/2003

# The Knowledge Base

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## Our underlying Dynamic Process XML/XSL technology makes it possible

- Maintenance-based processes
  - planned maintenance, shipboard troubleshooting, intermediate and depot level maintenance, ...
- Web-based and other graphical interfaces
  - XML representations with XSL transformations: the master enabling technology
- Process-based “actionable” data
  - Process flow, process state, user action sequence, user input, system status, ...

# What is XML?

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- eXtensible Markup Language: a mechanism for describing the semantics of a document
  - <tag> describes the semantics of enclosed data </tag>
- Grand vision: “The Semantic Web”
- Problem: what *are* the semantics?
  - Without defined semantics, no value added



# Electronic Manuals: Next Wave

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- Electronic Manuals must do more than just save paper
  - Not enough to just put the paper in the computer
  - Need the computer to *understand* the manual
- Semantics: general view of what happens in maintenance
  - Enables automated capture of repair/maintenance history

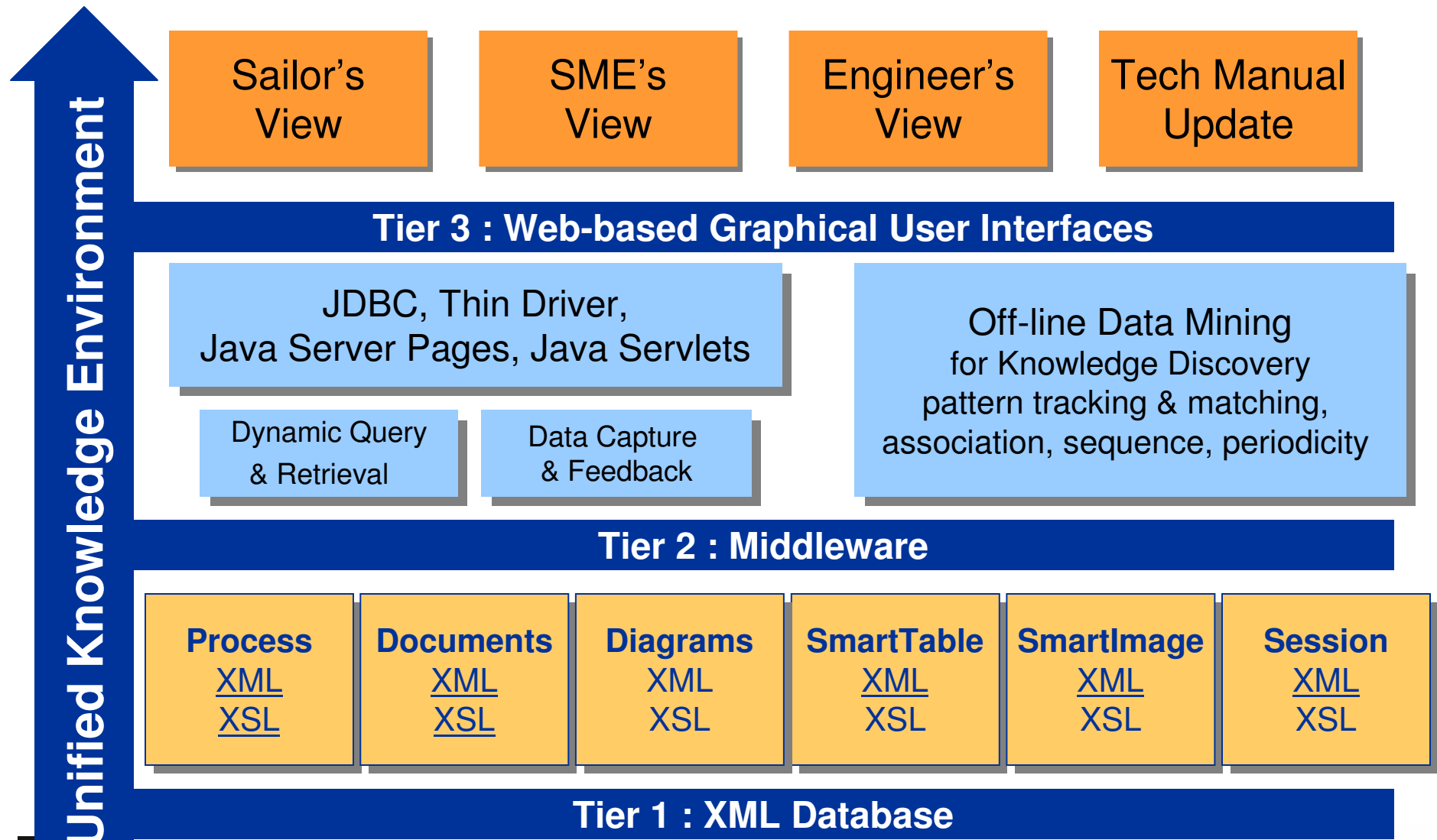
# Knowledge Base Components

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- **Dynamic Process**
  - Step-by-step description of events, decision points, drill-down points, data requests, user input requests, system status requests, ...
  - Data linkage across all relevant information
  - Bridging the “disconnect” between process actions and part issue
- **Linkage to Support Information**
  - Documents, Diagrams, smartTables, smartImages, Components, non-traditional data (emails, hotline), ...
  - Representing content through metadata, linkage, data selection, dynamic information creation, tagging, keyword search ...
- **Linkage to Data Mining**
  - Tightly coupled with dynamic process events
  - Real-time data capture & feedback with off-line analysis & mining
  - Multilevel view: from single fault resolution to end-to-end system fault diagnosis and repair
  - Opening up opportunities to streamline the maintenance process



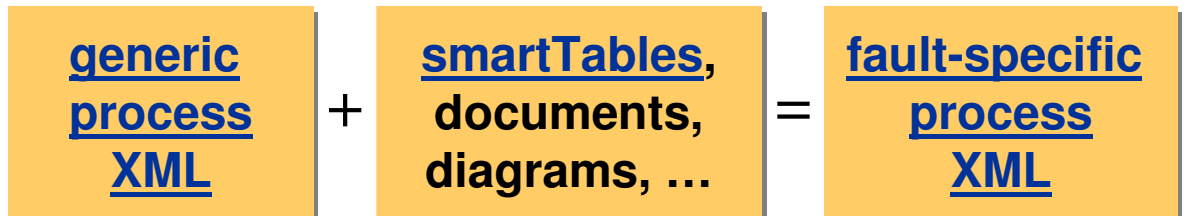
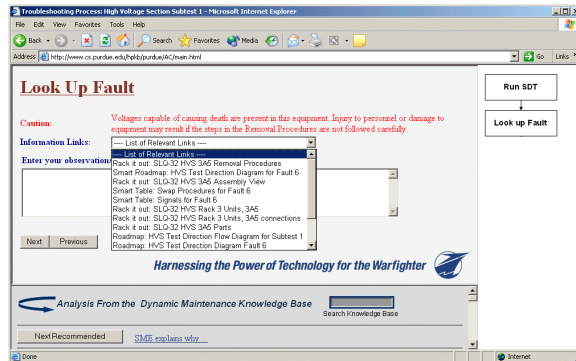
# Knowledge Base Infrastructure





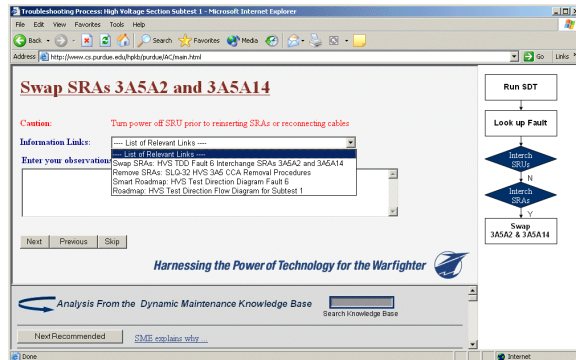
# Dynamic Process Data Flow

process scenario ID="SLQ-32 HVS Subtest 1 Fault 6"



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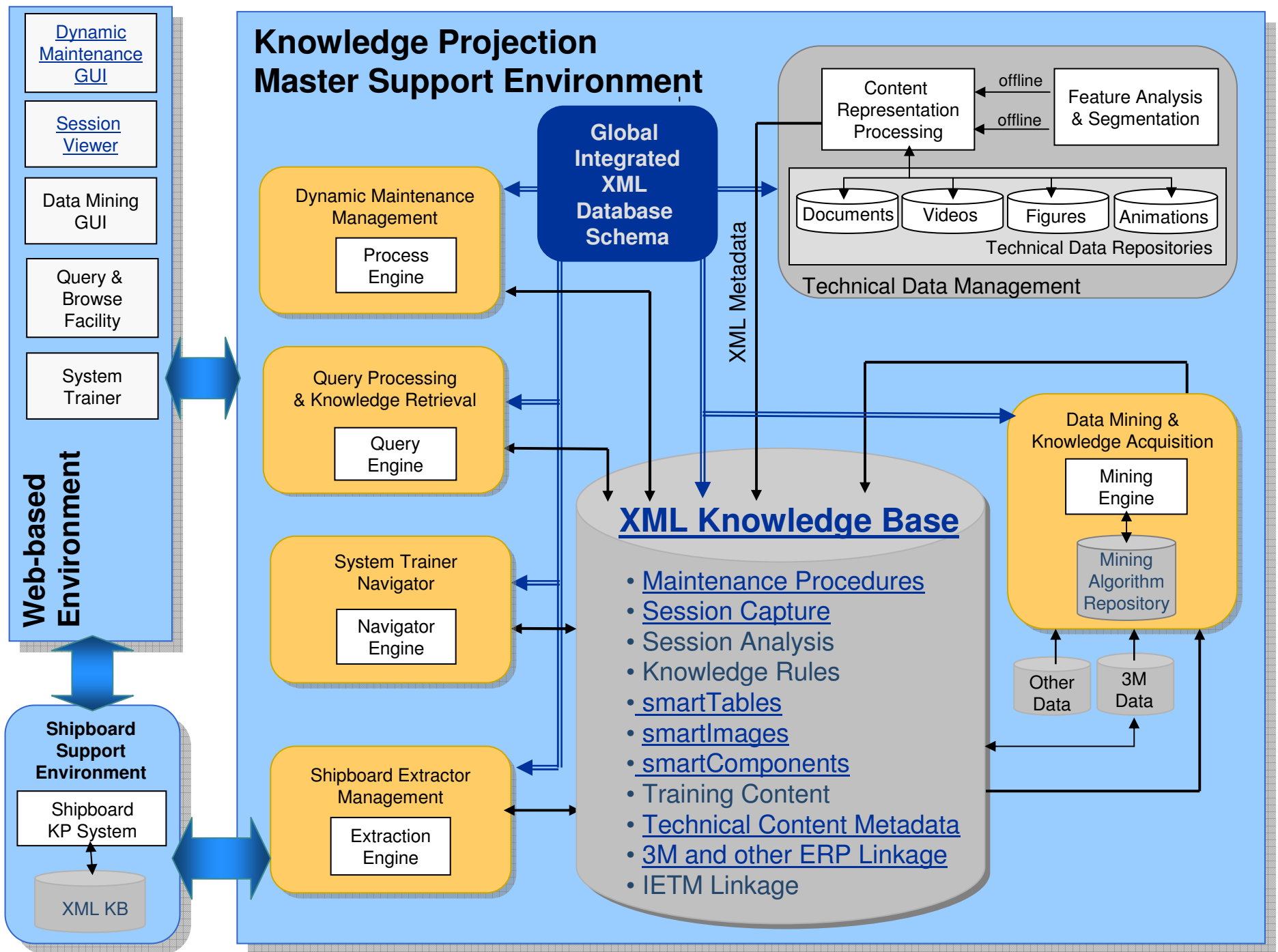
Query Database for Fault-specific TDD Data



Return & Display TDD Data

XML  
Knowledge  
Base

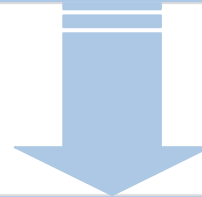




# XML Knowledge Base

The XML Knowledge Base supports the Knowledge Projection infrastructure, providing

- dynamic maintenance and knowledge-based query capabilities
- complete technical information linkage, including annotated and segmented manuals, diagrams, videos, animation, non-traditional data types and knowledge objects
- data mining methodologies based on dynamic maintenance capture and linkage to all relevant data

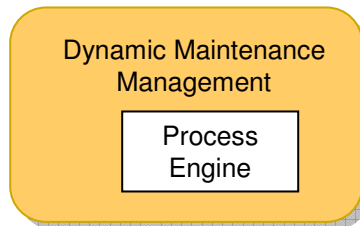


Codified maintenance procedures  
Representations of data to drive maintenance  
Links to repositories of technical data  
Metadata & query data  
Data mining-generated analysis and rules  
Specialized non-traditional data types  
Ontology  
Hierarchical, navigable description of systems

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# Dynamic Maintenance Management



The Dynamic Maintenance Management component handles execution of the official codified diagnostic and planned maintenance procedures, which are modelled in the Knowledge Base by the Process XSD. The process is a core XML knowledge object in the Knowledge Projection infrastructure.



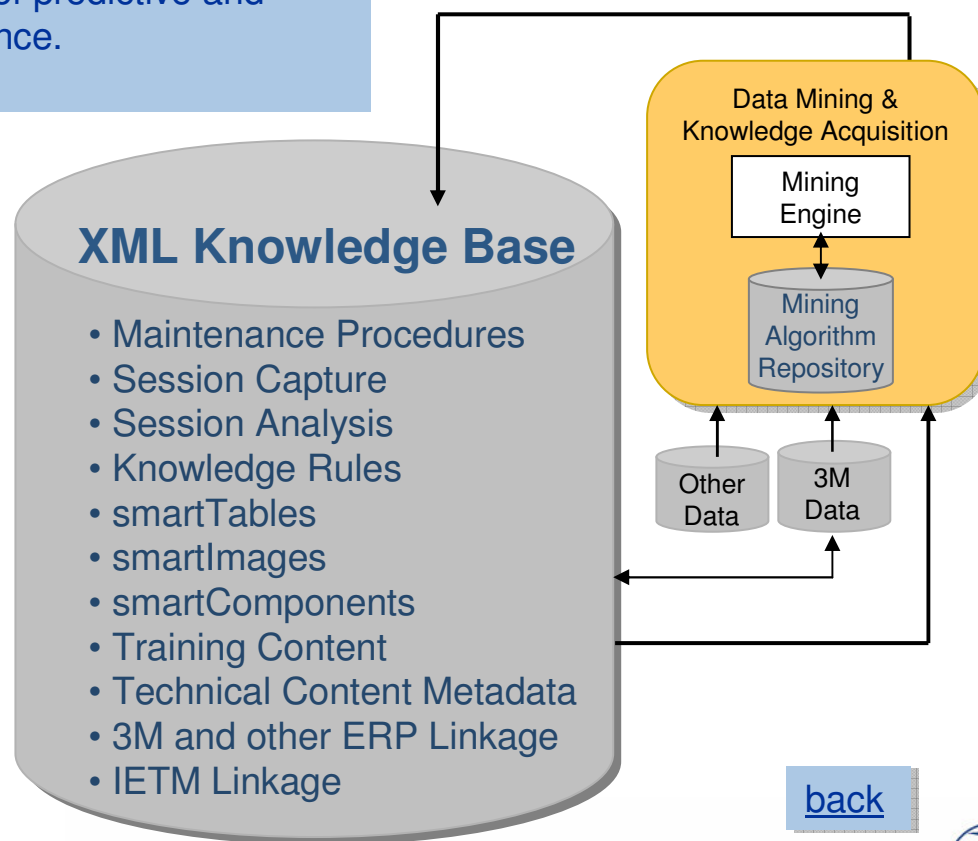
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# Data Mining

The Data Mining component provides statistical analysis and mining of data captured from dynamic process execution and other data sources. Mining is used to streamline codified procedures based on process-, fault-, action- and part-related data. Mining is also used to track and analyze fault and part replacement patterns, experiences, narratives and environment factors, with the goal of predictive and preventative maintenance.

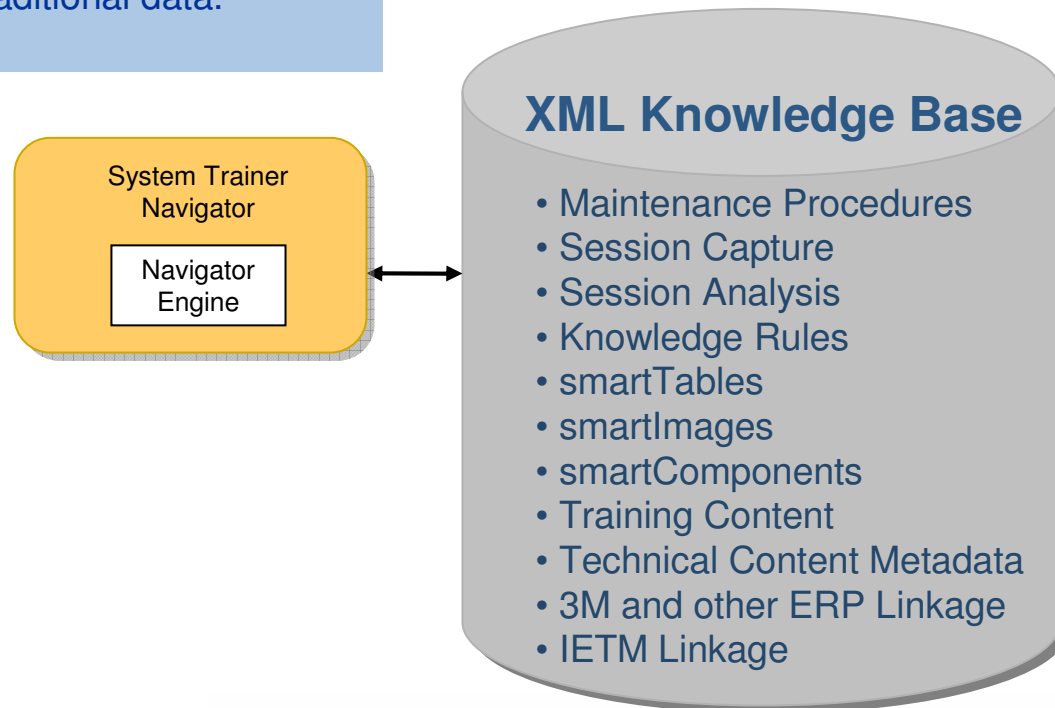


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# System Navigator

The System Navigator component operates as a training environment to support the multi-media navigation and investigation of the onboard systems to be maintained, providing a more complete understanding of system components through linkage to all Knowledge Base content, including annotated documents, diagrams, images, video, animations, and non-traditional data.

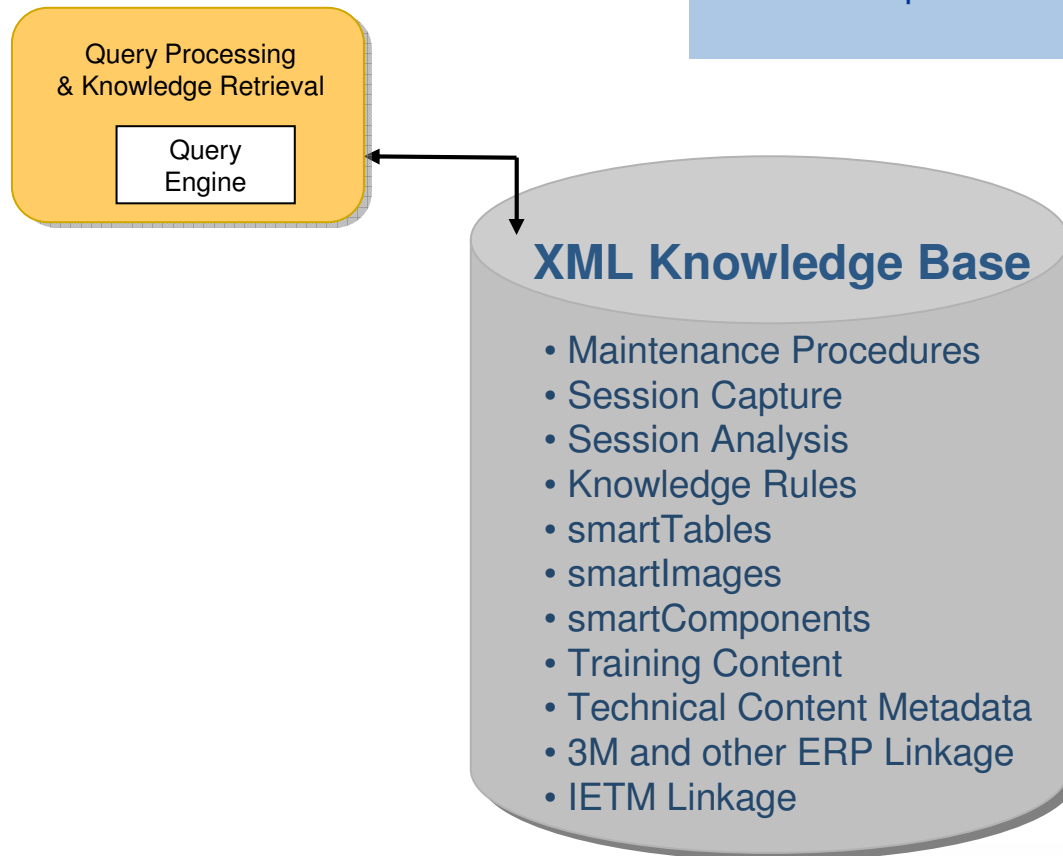


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# Query Processing & Knowledge Retrieval

The XML metadata, query keywords and linkage elements allow all Knowledge Base content to serve as query targets for the Query Processing component for knowledge search and retrieval.



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# XML Database Schema

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## Global Integrated XML Database Schema

- standardized element blocks for metadata and classification
- standardized elements blocks for query keywords to support knowledge query and retrieval
- standardized mechanism for linkage and connectivity among all XML objects in the Knowledge base
- standardized mechanism for data transformations within the database
- standardized mechanism for component-database and inter-component communication
- syntax standards for element tags and attributes







# The Knowledge Base Target

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- A unified and standard look for all components of the Knowledge Base, encompassing all the information needed to access and retrieve the components.
- All Knowledge Base components linked and working together to support Dynamic Maintenance execution, Data Mining with session capture and feedback, Query Processing with knowledge search and retrieval, and Component Navigation for training.
- Guidelines, standards and quality measures for schema design to be followed by both Purdue and Indiana Universities, which are checked during schema integration and delivery of the unified Knowledge Base.





# Knowledge Base Standards

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- Define an XSD for a library of tags shared by all components, to guarantee consistency among them.
- Define an XSD for each KB component, and validate all the XML instances against the XSD.
- Restrict each component XSD to have a minimal set of shared tags. Examples: ID, KeyWords, ClassInformation, and SourceDocument.
- Provide a standard way to define the linkage between the different KB components.
- Define scripts that automatically perform strict validation of the XML instances against their XSD and load the instances in the database.
- Define XSLT from XML to HTML to allow users to browse and view all KB components.
- Provide guidelines for ownership and delivery of the KB, describing in detail the definition, quality measures, validation and verification process to be applied for all delivered KB components.



# Knowledge Base Components

- **Maintenance Procedures**

- Step-by-step description of standard maintenance procedures with user and database interactions and data linkage across all relevant information
- Bridging the “disconnect” between process actions and part issue

- **Linkage to Support Information**

- Relevant support information needed by all the functional components.
- Representing content through metadata, linkage, data selection, tagging, keyword search ...

- **Linkage to Data Mining**

- With the dynamic maintenance execution there is a real-time data capture & feedback with off-line analysis & mining
- Multilevel view: from single fault resolution to end-to-end system fault diagnosis and repair
- Opening up opportunities to streamline the maintenance process

- **Linkage to Query and Training Components**

- All KB components are accessible for query and training.
- Complete system interaction and accessibility.

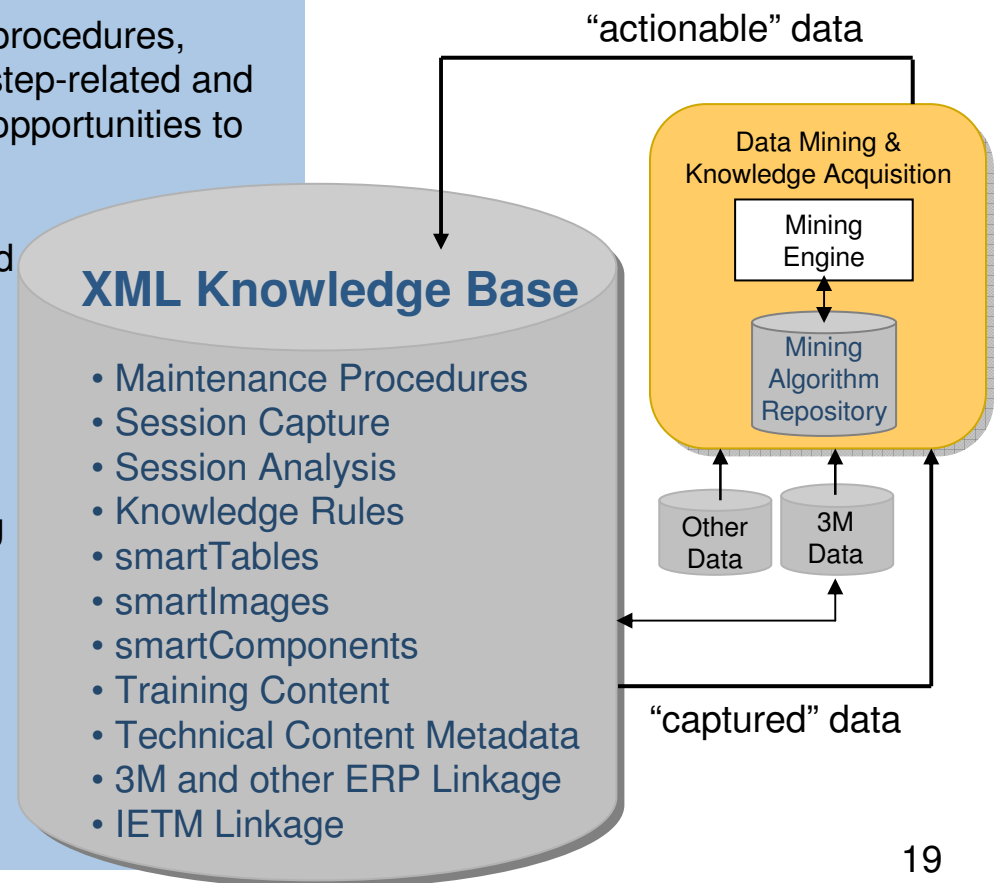
## XML Knowledge Base

- Maint. Procedures ([xml](#))
- smartTables ([def](#),[inst](#),[rows](#))
- [smartImages](#) ([xml](#))
- smartComponents ([xml](#))
- Content Metadata ([xml](#))
- IETM Linkage
- Session Capture ([xml](#))
- Session Analysis
- Knowledge Rules

- Provide **statistical analysis directly related to dynamic maintenance** execution, where analyzed data is linked to the current fault, the current diagnostic procedure, the current step in the procedure. This action sequence and related data is captured as sessions and analyzed offline. SessionsViewers **target specialized audiences**, since sailors, engineers, technicians and other SME's each have their own "window of interest" in the analysis.
- Identify **alternative paths** to the codified procedures, based on procedure-related, fault-related, step-related and part-related data. Alternate paths open up opportunities to streamline the maintenance process.
- Track, analyze and mine fault patterns and part replacement patterns to **uncover predictive patterns** and determine possible preventative maintenance.
- Track and analyze environmental factors, narratives, observations, experiences (including emails, text chat, etc) through **text mining** to produce recommendations during diagnostic troubleshooting.
- Incorporate relevant **external data** (e.g., 3M database) to the mining process

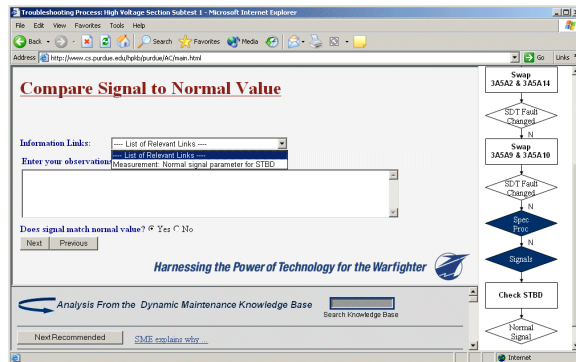
## Data Mining and Knowledge Discovery

Action-based Data Mining  
 FaultSession-based Data Mining  
 Session-stream Data Mining  
 Sensor Data Mining



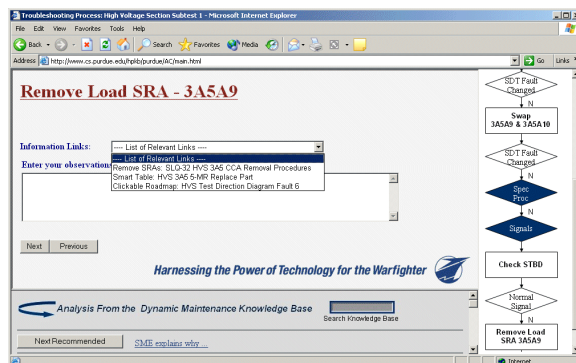
# Dynamic Knowledge Data Flow

process scenario ID="SLQ-32 HVS Subtest 1 Fault 6"



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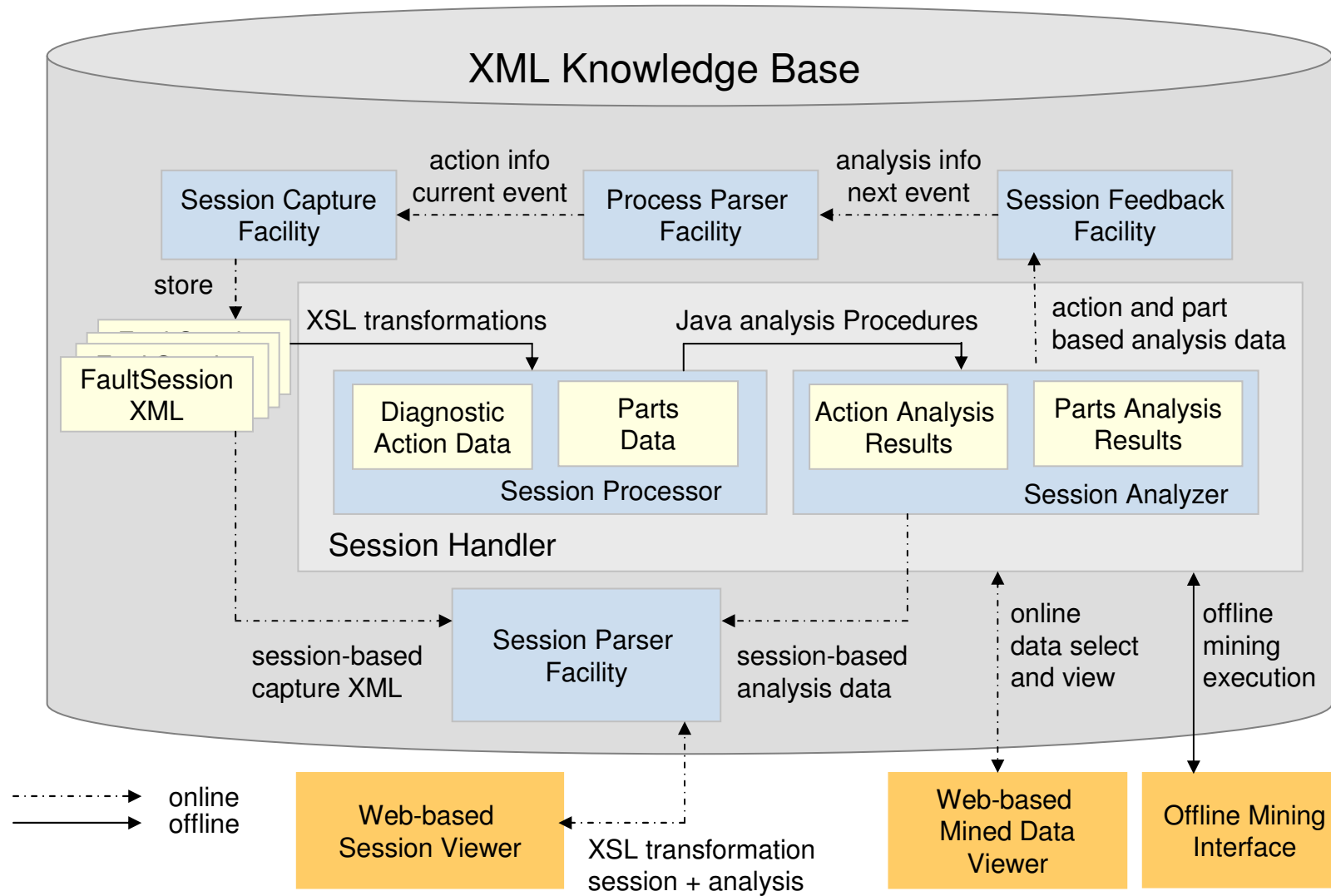
Feed

## Capture to Session

- ☐ Sequential order of actions
- ☐ Decision point evaluations
- ☐ Action "state data" (fault list, state & order of fault resolution, current SRUs, SRAs, signals, ...)
- ☐ Action time stamp and time duration
- ☐ Linked document & diagram requests, queries to the KB
- ☐ Email, hotline support requests, collaborations
- ☐ Visual observations, experiences, expertise
- ☐ Environment factors
- ☐ Measurement value, SF status tables
- ☐ Sensor and other system generated system state data

# Design of the XML Knowledge Based Components for Data Mining

## Module design, interfaces and interactions



## Data Mining and Knowledge Acquisition

Automatic capture of action, fault session and session stream-based data from thousands of actual executions of the diagnostic and planned maintenance procedures

- plus linkage and access to existing technical, maintenance and parts data repositories
- plus data filtering and transformation

### **Automatic capture of all “fault session” data : resolution of a single fault**

sequential order of actions

decision point evaluations

action time stamps and duration

current action SRAs & signals

normal signal parameters and actual measured values

resource requests with usefulness metric

emails, text chats, requests for help, SME interaction

visual observations, narratives, experiences, environmental factors

special function status table, bit monitor values

sensor and other system generated state data

### **Capture of all “fault stream” data: resolution of all faults generated by the SDT**

SDT fault list for through final resolution

order of fault resolution

tagging of intermittent faults, shadow faults, cascading faults

inter-session visual observations, narratives, experiences

inter-session environmental factors

session and diagnostic procedure relationships



# Data Mining and Knowledge Discovery

## Diagnostic Action Histories

action duration analysis: average, min, max with narrative linkage  
tracking of resource accessed (documents, diagrams, emails, help)  
tracking of parts accessed  
measurement values and system status  
action bypass

## Diagnostic Session Histories

session trigger stats -- weekly SDTS, operational failure  
action sequence analysis -- track action flow to isolate faulty part  
time-series analysis of action flow over all possible procedure paths

## Parts Histories

last access date, last replacement date  
age, average lifetime  
failure frequency -- fault specific and overall

## Text Mining

visual observations, narratives, experiences  
emails, text chats, requests for help, SME interaction

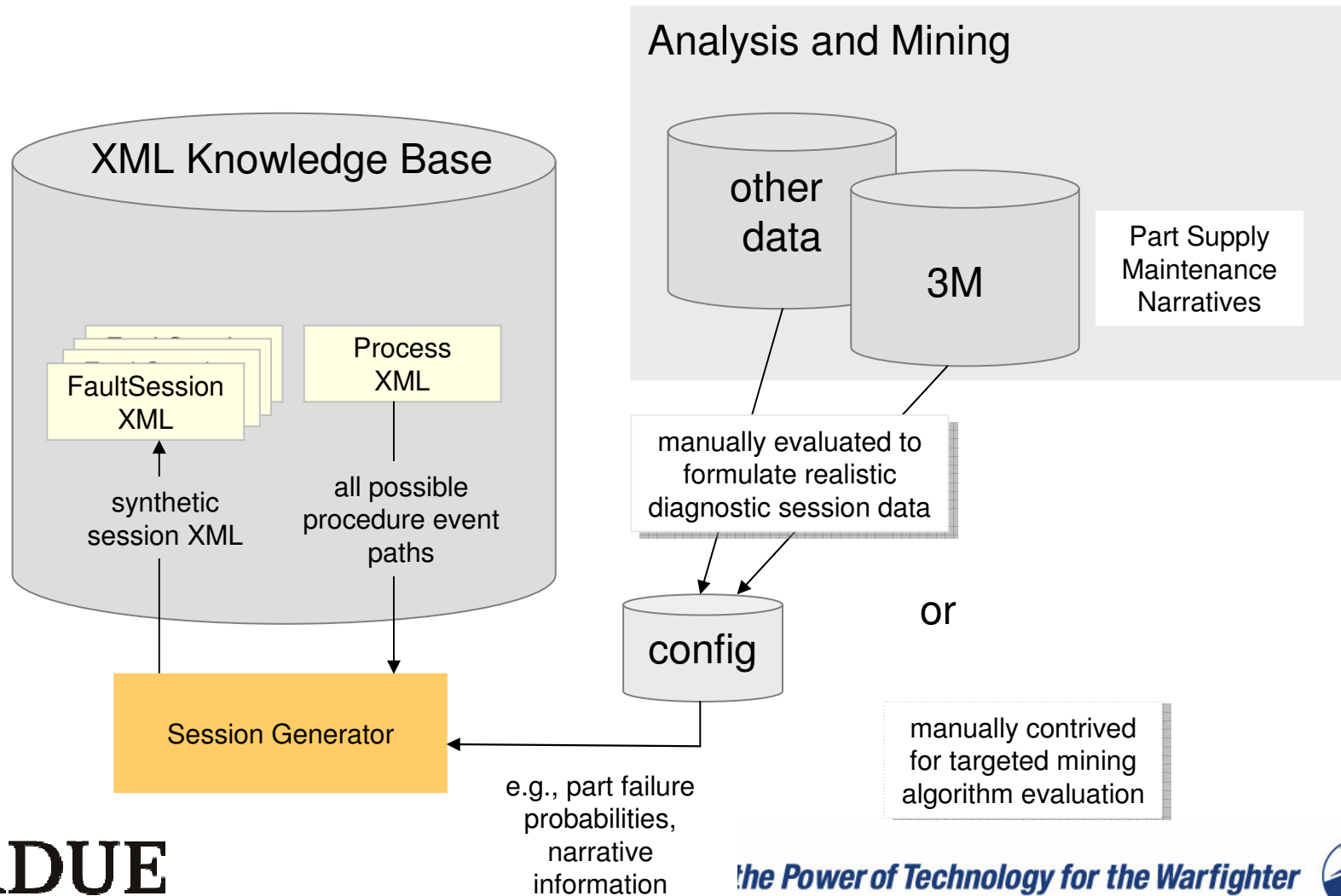
## Fault Stream Histories

pattern analysis for fault resolution (before/after groupings)  
inter-session relationships (association, sequence)  
discovery of predictive patterns for preventative maintenance

## Fleetwide, ship type, ship class, own ship



# Generation of Synthetic Session Data for Testing, Validation and Evaluation plus Analysis and Mining of the 3M Database with Focus on Text Mining





# Knowledge Base for Dynamic Maintenance

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- Outcome: Knowledge of Product Throughout its Lifecycle
  - Flexible Delivery of Repair and Maintenance Procedures
  - Automatic Collection of Repair and Maintenance History
  - Better Understanding of Product Use and Failure



# Pursuing Dual-Use

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- Contributing to Research on Product Lifecycle Management
  - Corporate-Funded Center
- Companies See the Value
  - Feedback to Engineers
  - Reduced end-of-lifecycle costs
- Looking for Corporate Collaboration
  - Presented to Arvin Meritor
  - Included in proposal to Caterpillar