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Knowledge-Projection for Tele-Maintenance

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The Purdue Knowledge Projection Group

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

Indiana Center for Database Systems

Harnessing the Power of Technology for the Warfighter

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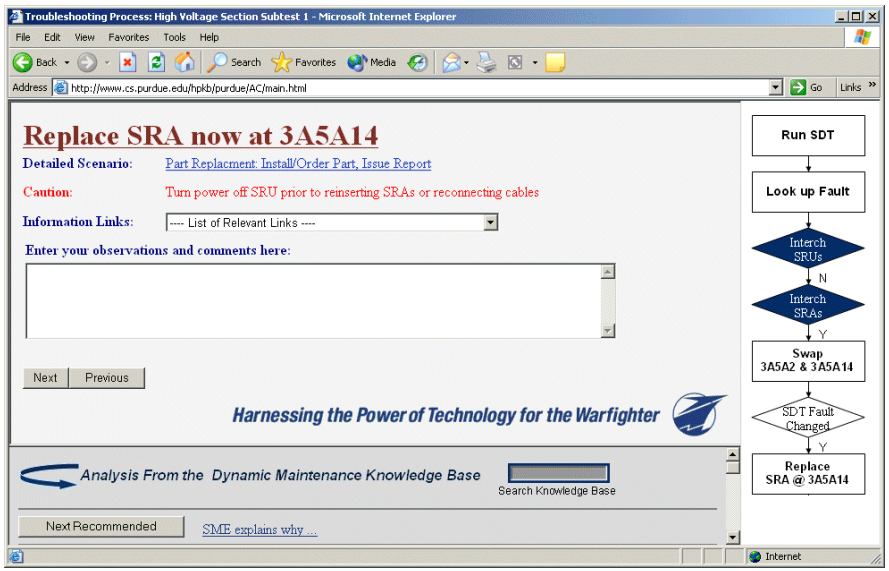
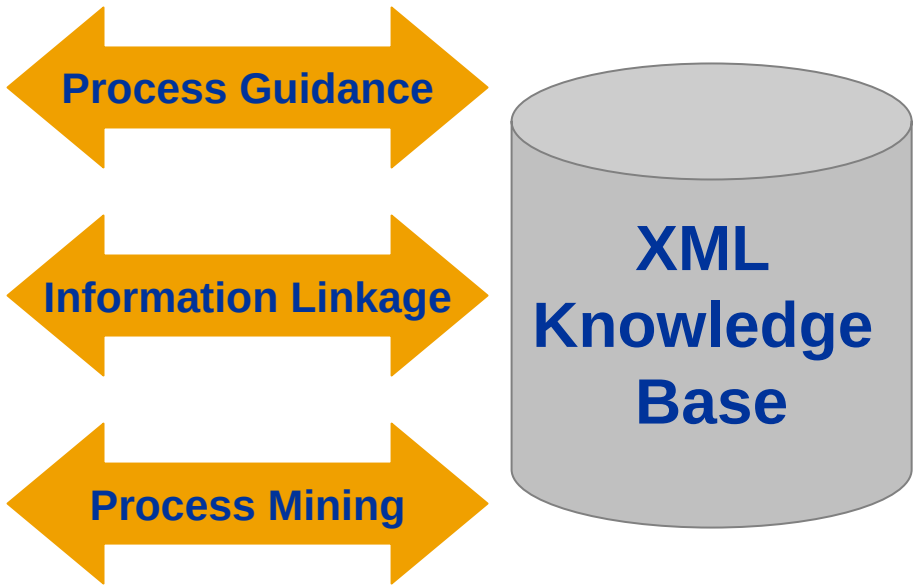
RAB6

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 "

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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

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?

- 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

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Electronic Manuals: Next Wave

- 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

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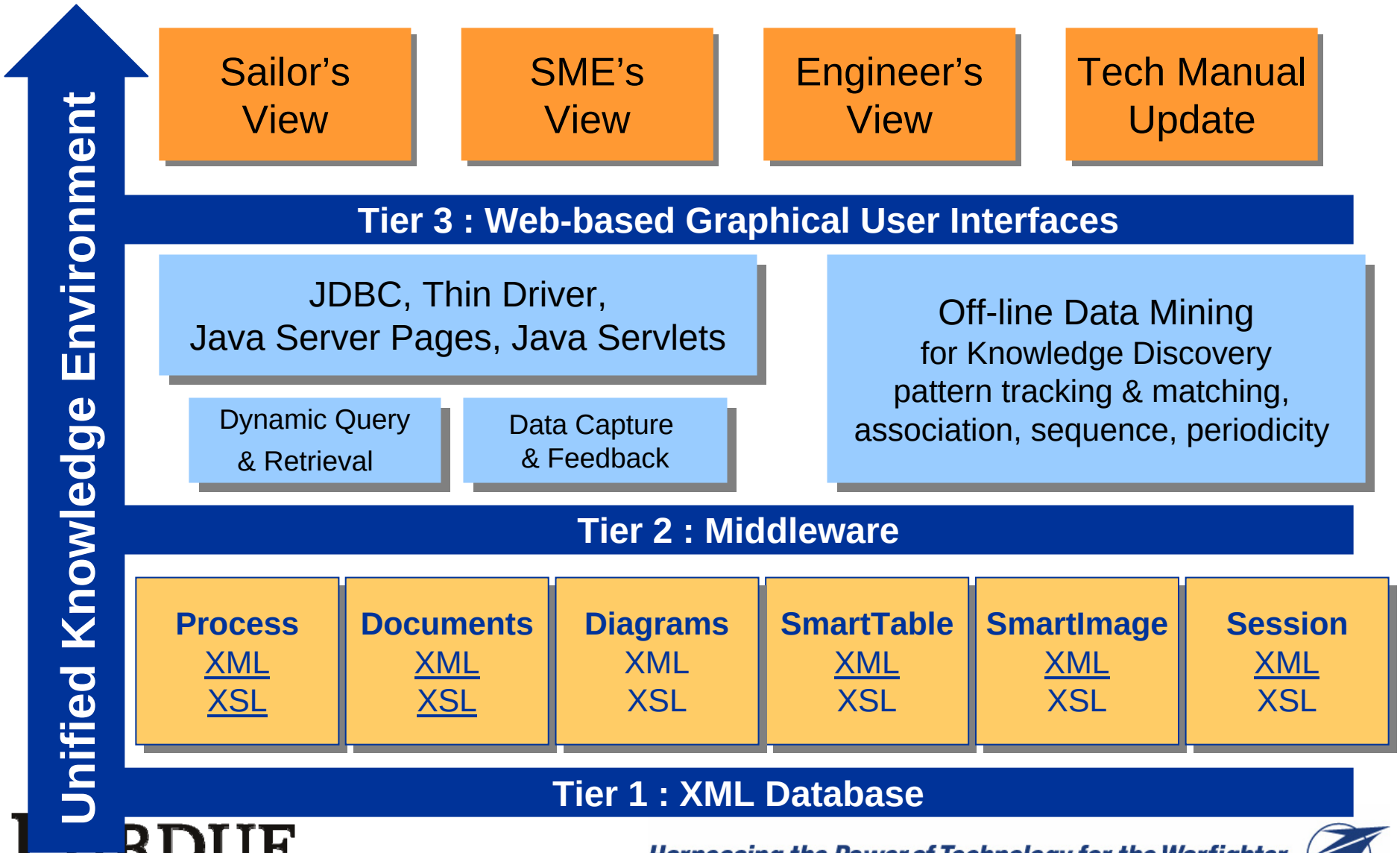
Knowledge Base Components

- **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



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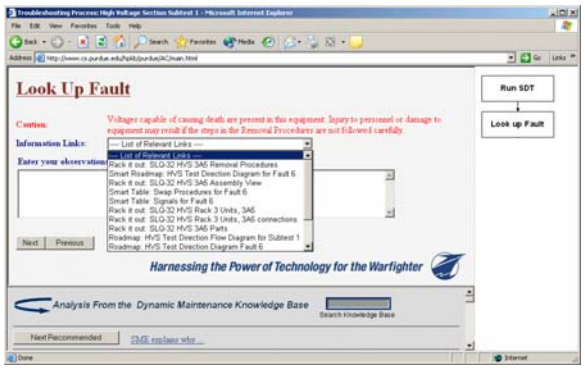
Dynamic Process Data Flow

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

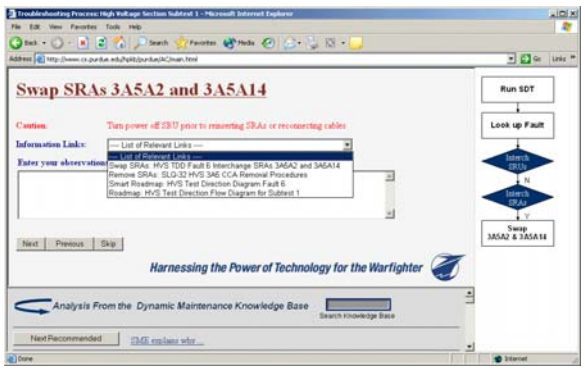


generic process XML + smartTables, documents, diagrams, … = fault-specific process XML

next

Query Database for Fault-specific TDD Data

XML Knowledge Base



Return & Display TDD Data

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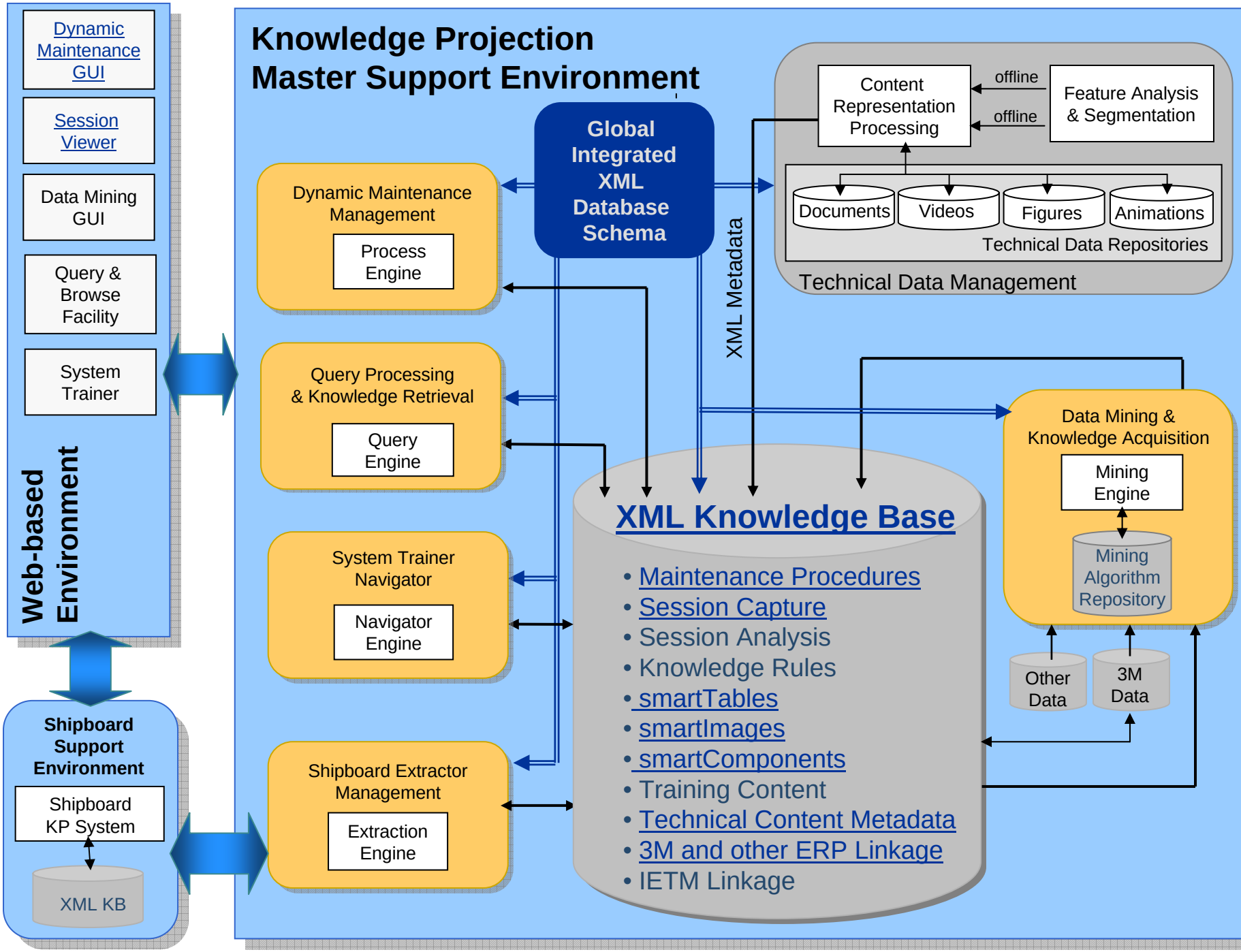
Knowledge Projection
Master Support Environment
Dynamic Maintenance GUI
Session Viewer
Data Mining GUI
Query & Browse Facility
System Trainer
Web-based Environment
Shipboard Support Environment
Shipboard KP System
XML KB
Global Integrated XML Database Schema
XML Metadata
Content Representation Processing
offline
offline
Feature Analysis & Segmentation
Documents
Videos
Figures
Animations
Technical Data Repositories
Technical Data Management
Dynamic Maintenance Management
Process Engine
Query Processing & Knowledge Retrieval
Query Engine
System Trainer Navigator
Navigator Engine
Shipboard Extractor Management
Extraction Engine
XML Knowledge Base
• Maintenance Procedures
• Session Capture
• Session Analysis
• Knowledge Rules
• smartTables
• smartImages
• smartComponents
• Training Content
• Technical Content Metadata
• 3M and other ERP Linkage
• IETM Linkage
Data Mining & Knowledge Acquisition
Mining Engine
Mining Algorithm Repository
Other Data
3M Data

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The Knowledge Base Target

- 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

- 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.

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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.

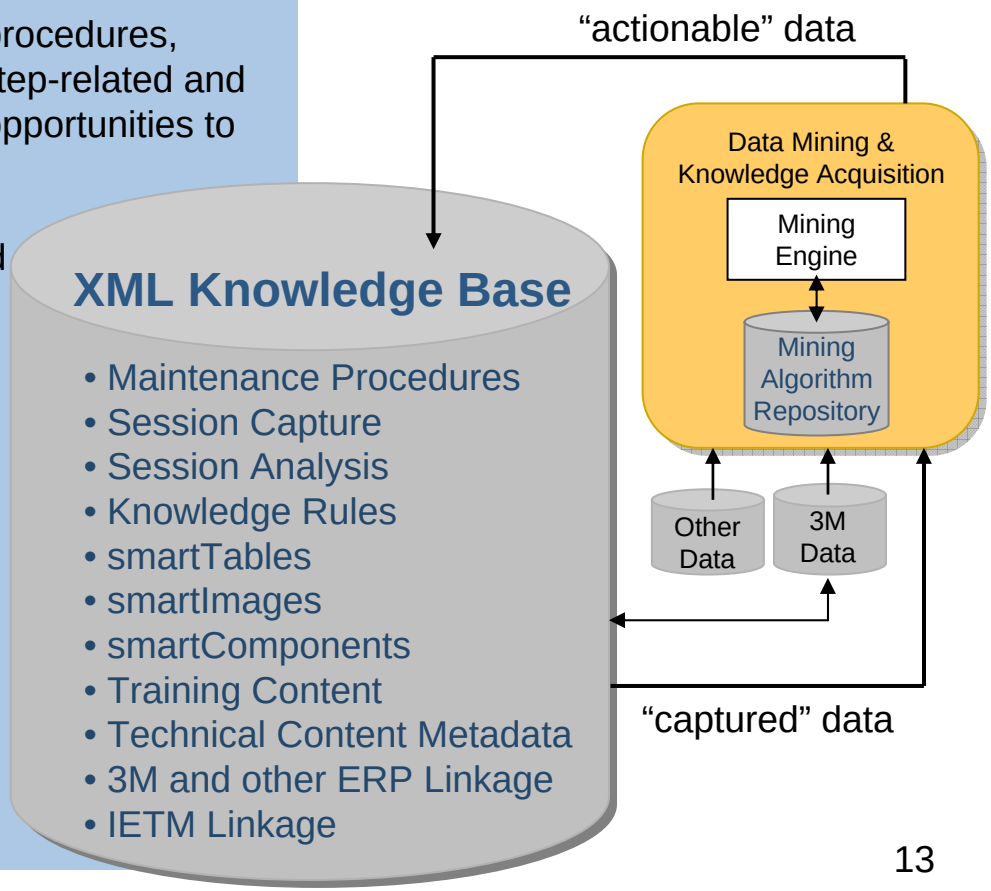
- Track, analyze and mine fault patterns and part replacement patterns to **uncover predictive patterns** and determine possible preventative maintenance.

- 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

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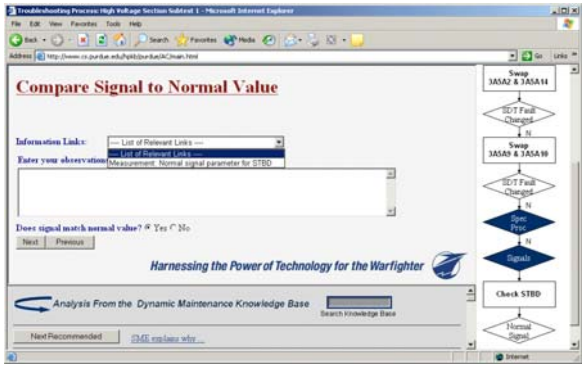
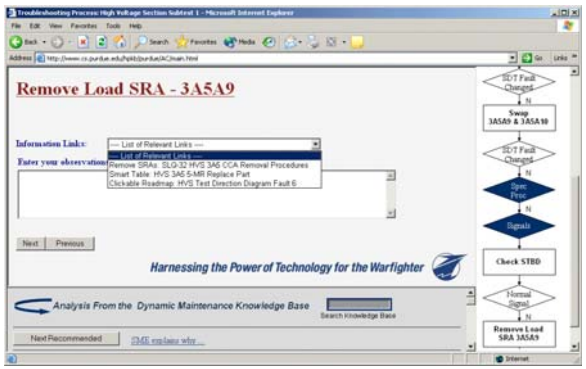


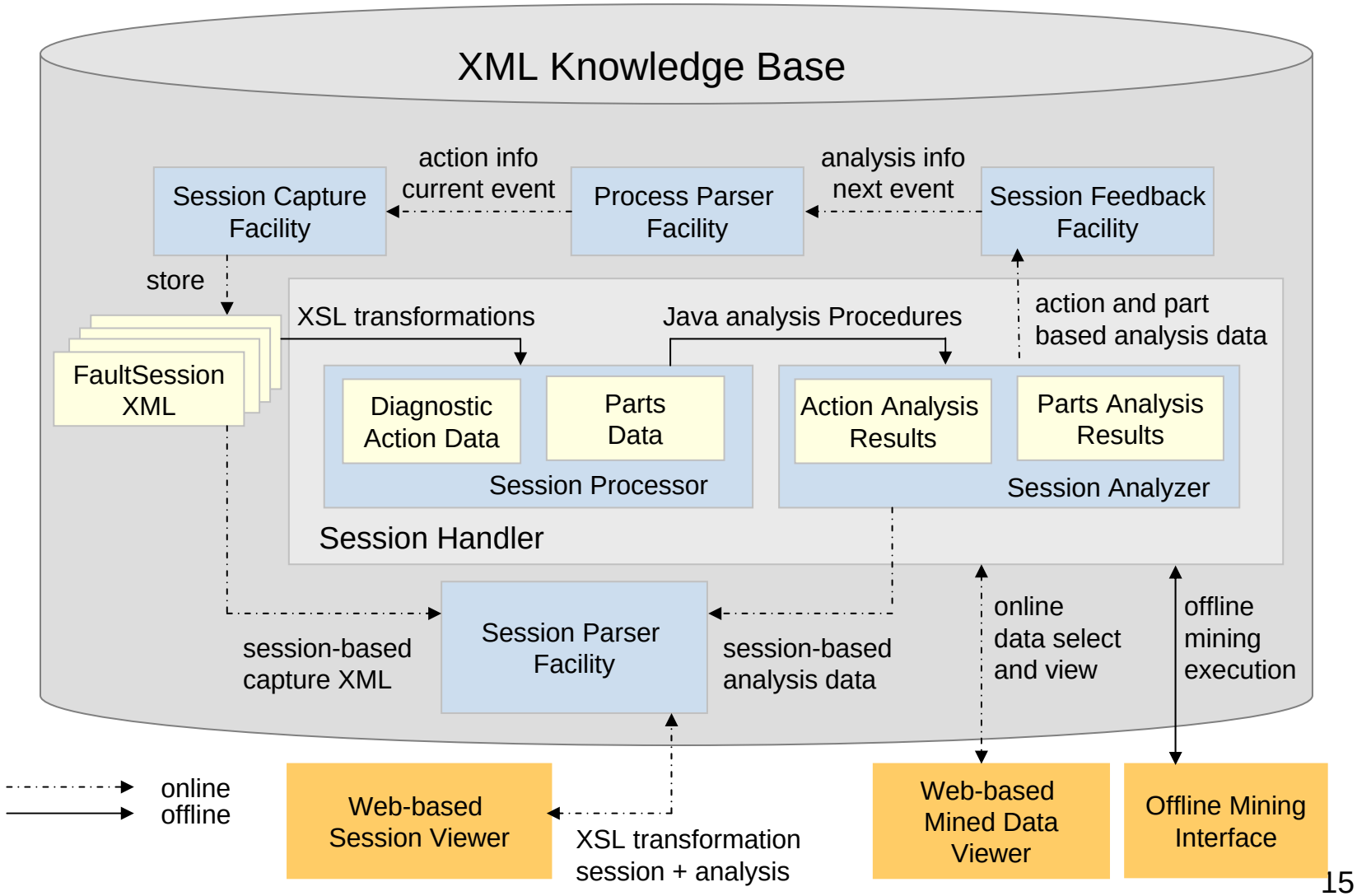
next



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

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Knowledge Base for Dynamic Maintenance

- 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

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Pursuing Dual-Use

- 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