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Knowledge-based Systems for Dynamic Maintenance

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The Purdue Knowledge Projection Group for NSWC Crane
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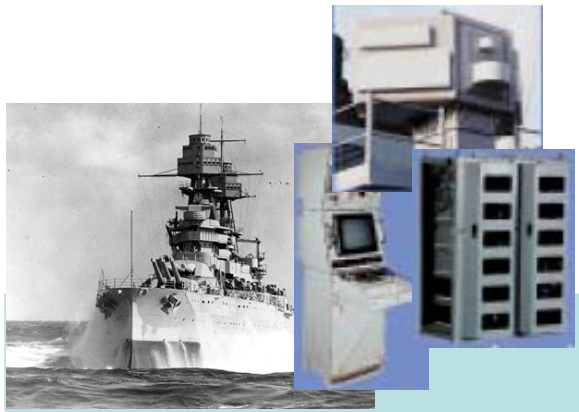
Targeting Maintenance

… a million maintenance events
… a hundred thousand corrective actions
… millions of man hours
… ? critical failures



Raytheon AN/SLQ-32
Shipboard ECM System
detects and identifies search and targeting radar; responds to confuse and divert launched missiles

- Planned Maintenance
- Corrective Maintenance

1980 1990 2000

Effective maintenance procedures …

- Support maintainer throughout diagnosis and repair
- Increase operational availability and readiness
- Lower the total cost of ownership

That's a good start, but ….

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Revolutionizing Maintenance

A new concept for representation of maintenance procedures

- Guided step-by-step processing
- Action-based resource access
- Automatic web-based presentation
- Automatic session capture
- Session packaging for transmit
- Session analysis for knowledge discovery

A new philosophy for maintenance … pro-active not reactive

… a dynamic, knowledge-based system, supported by an infrastructure that allows us to learn continuously from the maintenance process itself.

Triggers … Failures … Actions … Observations … Parts…

Failure Patterns … Relationships … Root Causes …

Dynamic? Knowledge-based?

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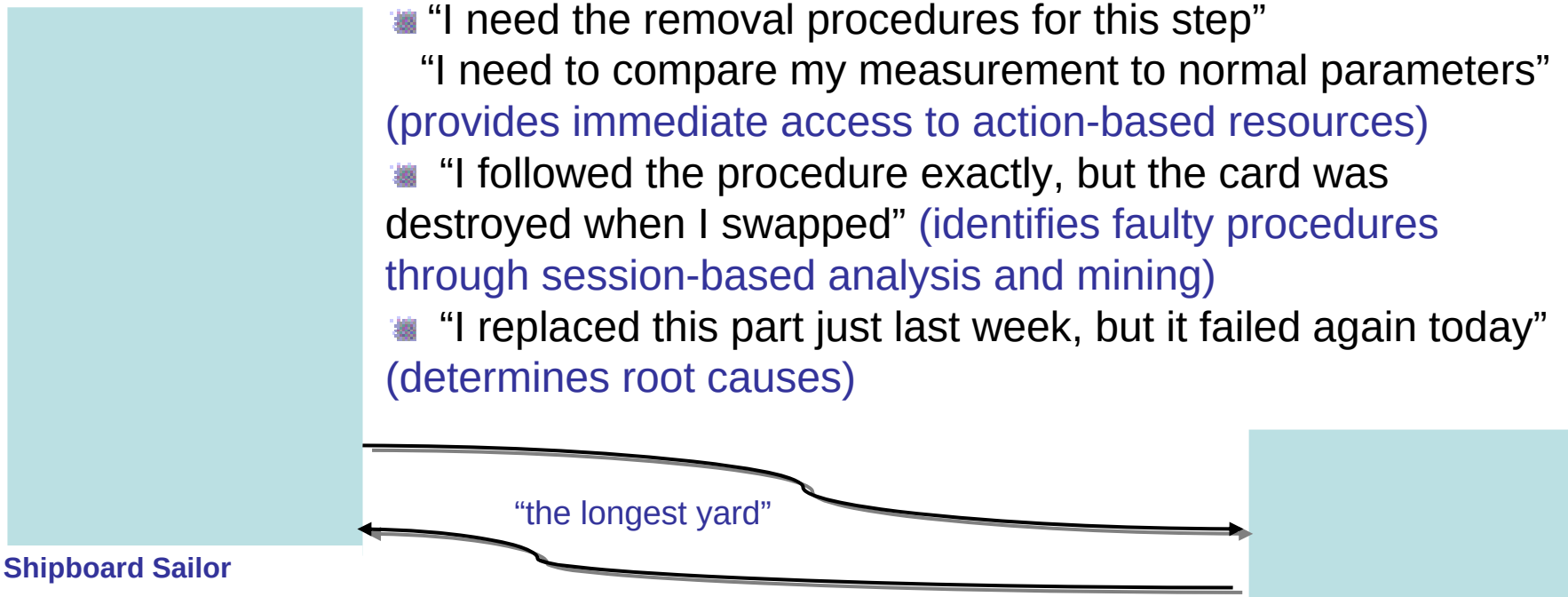
- "I need the removal procedures for this step"
  "I need to compare my measurement to normal parameters"
(provides immediate access to action-based resources)
- "I followed the procedure exactly, but the card was destroyed when I swapped" (identifies faulty procedures through session-based analysis and mining)
- "I replaced this part just last week, but it failed again today" (determines root causes)



- "Describe in detail everything you tried so far for this fault – especially anything usual?" (serves collaborative maintenance)
- "This load CCA seems to fail consistently with this signal" (identifies engineering design problems)
- "What action sequences have been taken to resolve the many failures for this switch?" (links part replacement to diagnostic actions)

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The Research Effort – Part 1

- Enabling technologies for capture, analysis and delivery of maintenance data
  - XML representation of maintenance procedures to handle the enormity and complexity of any action and associated data
  - Creation of XML content at earliest stages of manufacturing
  - XSL transformations for automatic web-based presentation
  - Action-based linkage to external & internal resources
  - Automatic session capture
  - Integration of non-traditional data types
  - XML representation of captured session for web-based presentation
  - Session packaging for ship-shore communication
  - Session processing for dissemination of tacit knowledge, observations and experiences

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The Research Effort – Part 2

- Session-based knowledge discovery to support predictive and ultimately preventive maintenance
  - Action statistics & resource tracking
  - Action sequence analysis and streamlining
  - Diagnostic history & failure-part analysis
  - Action & session-based feedback
  - Failure trigger & fault pattern analysis
  - Intermittent/ shadow/ cascading fault tracking
  - Text categorization framework for observation data
  - Incorporation of sensor data

- Knowledge Base
  - Guided procedures, captured sessions, smartTables, smartImages, metadata for resource linkage
  - Statistics, analysis & knowledge data
  - Code, client communication, queue/transmission/synchronization
  - Services offered to other Navy Projects

The Knowledge Projection System

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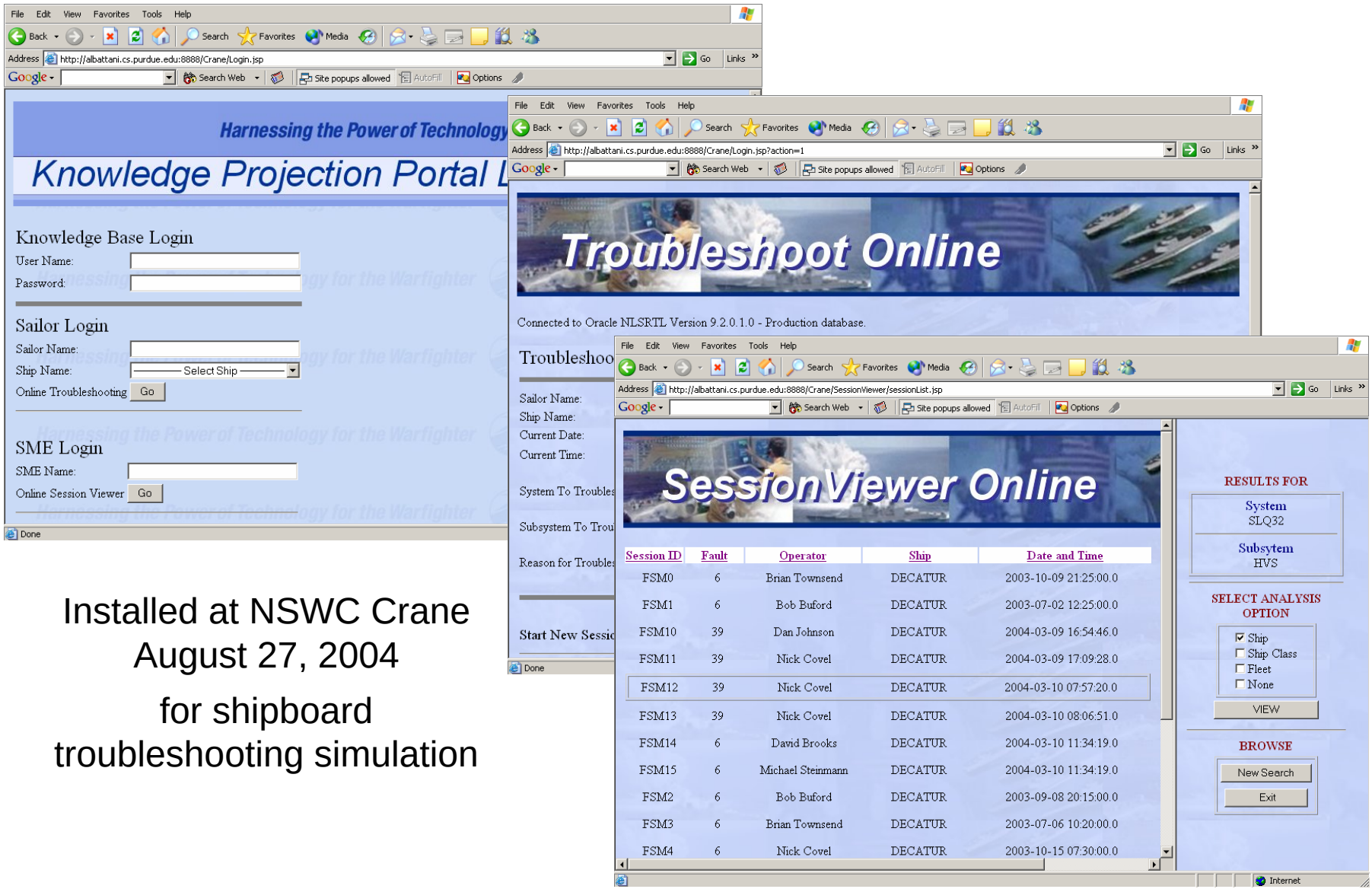

Session ID	Fault	Operator	Ship	Date and Time
FSM0	6	Brian Townsend	DECATUR	2003-10-09 21:25:00.0
FSM1	6	Bob Buford	DECATUR	2003-07-02 12:25:00.0
FSM10	39	Dan Johnson	DECATUR	2004-03-09 16:54:46.0
FSM11	39	Nick Covel	DECATUR	2004-03-09 17:09:28.0
FSM12	39	Nick Covel	DECATUR	2004-03-10 07:57:20.0
FSM13	39	Nick Covel	DECATUR	2004-03-10 08:06:51.0
FSM14	6	David Brooks	DECATUR	2004-03-10 11:34:19.0
FSM15	6	Michael Steinmann	DECATUR	2004-03-10 11:34:19.0
FSM2	6	Bob Buford	DECATUR	2003-09-08 20:15:00.0
FSM3	6	Brian Townsend	DECATUR	2003-07-06 10:20:00.0
FSM4	6	Nick Covel	DECATUR	2003-10-15 07:30:00.0

Installed at NSWC Crane
August 27, 2004

for shipboard
troubleshooting simulation

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The Knowledge Projection System

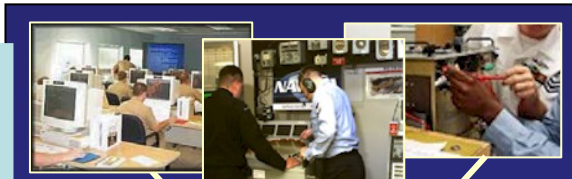
KB

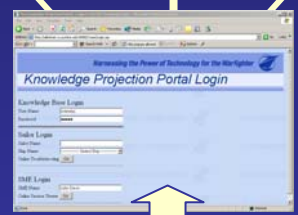
KB

KB

- Online Troubleshooting
- Session capture
- Session transmit & viewing
- Ship-shore synchronization
- Session analysis feedback
- Knowledge query

Shipboard KPS





XML
Knowledge Base

- Ship-shore synchronization
- Session transmit & viewing
- SME recommendation processing
- Data mining
- Knowledge discovery
- Knowledge query
- Maintenance streamlining, maintenance training, equipment engineering, management reporting, …

Shore-side KPS

Our Vision for Shipboard T/S

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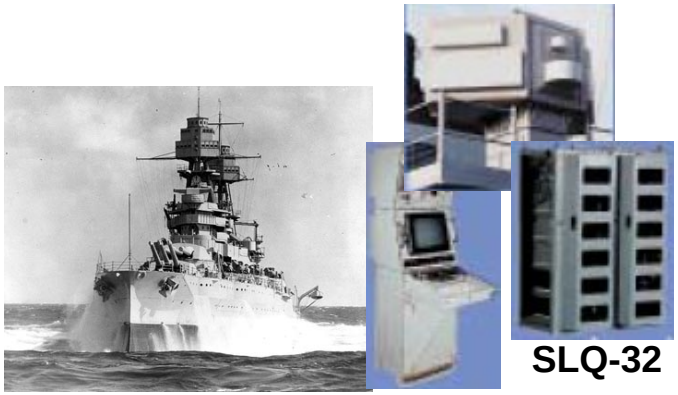


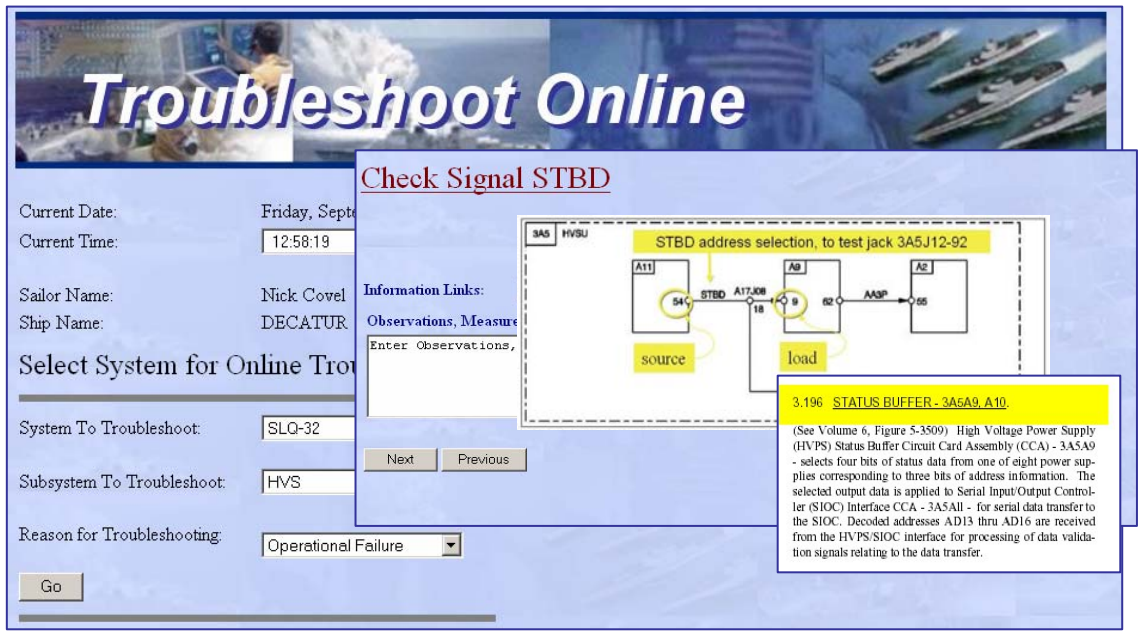
SLQ-32

EW

… while running the ULM-4 range, port driver and port repeater BIT lights activated, at the same time ULM-4 range reported an immediate …
… port forward high voltage distribution unit stuck relay …
… unable to transmit from STBD antennae …
… on the active side I noticed that when we are in AECM standby, power supply 3A3 for the port side has the high voltage light on, even though it isn't even on …
… I get no readings on any of the TWTs as I toggle them …
… I need to ask for advice on this problem since someone might have encountered it before and have an idea what is causing it. I think I have a bad TWT that might have caused the power supply and HVDU to go bad, but is it possible …
… HV stuck relay causes constant high voltage to be applied to output TWT, trips HV power supply offline causing leveling fault …

Troubleshooting Today

Our Vision for Tomorrow



We Deliver for the Sailors

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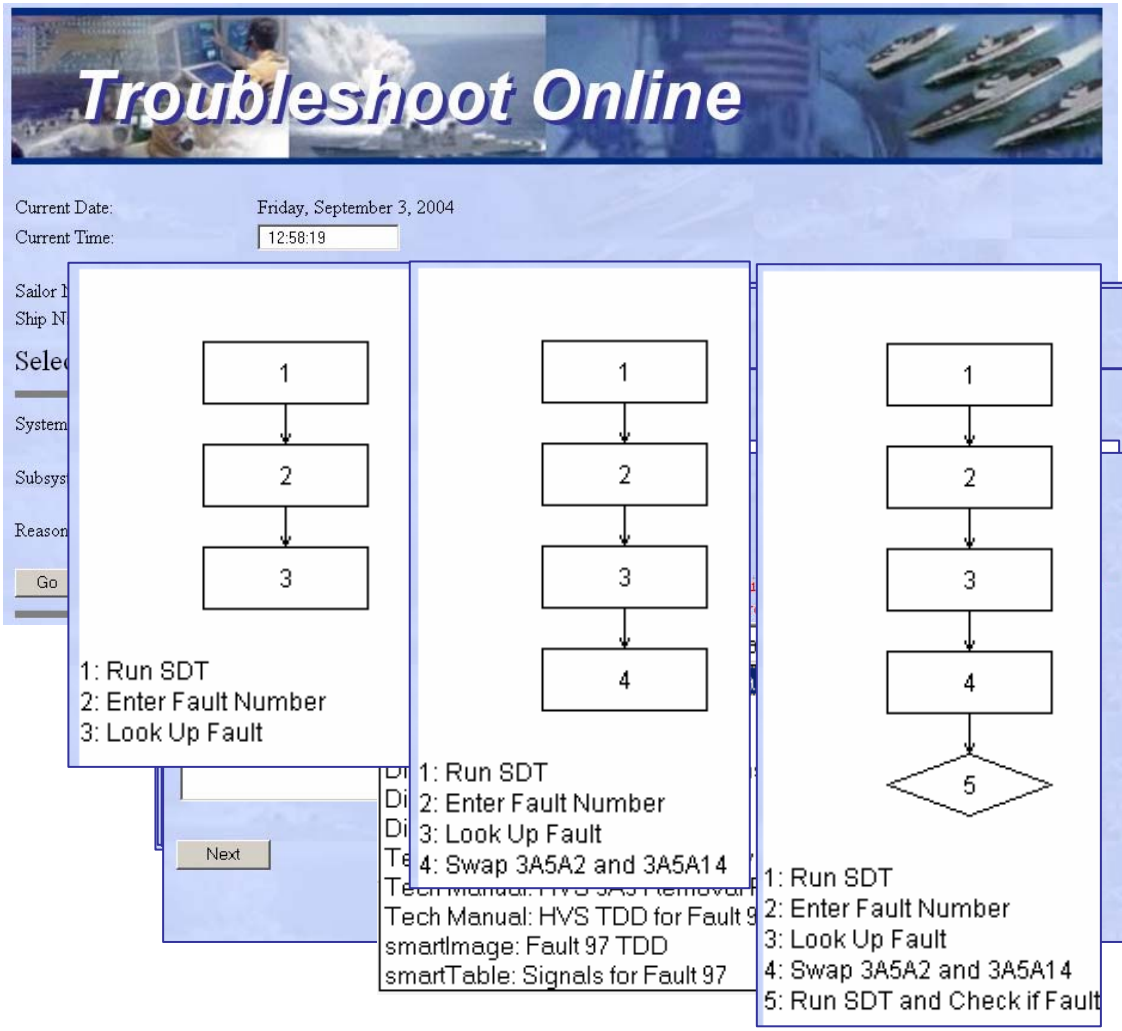

Online Troubleshooting …

- ✓ Presents online interface to troubleshooting procedures
- ✓ Follows codified procedures step-by-step
- ✓ ndles any form of special ures and incorporates them into the standard flow
- ✓ omatically retrieves tech ls, diagrams, tables at each step ickable links
- ✓ Presents information links in order of usefulness and supports search of knowledge base
- ✓ Visualizes diagnostic flow path as dynamically constructed flowchart

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We Capture Sessions

Troubleshooting action sequence for resolving a fault

Login Information from the Portal

Fault 6
Automatic Capture
TroubleshootScenario Subtest1
Operator ID EW1
Name Nick Covel
ShipID DECATOR DDG 73
ActionList

Action1
Subtest1 Event2 Look Up Fault
Comment HV stuck relay causes high voltage
TimeStamp Date 2003-10-09

Action2
Subtest1 Event8 Swap Interchangeable SRAs
Comment relay control card bad
TimeStamp Date 2003-10-09
Time 21:35:30

Action3
Subtest1 Event5 SDT Fault Report Change ?
Comment
TimeStamp Date 2003-10-09
Time 21:49:55
Answer YES
Elapsed Time 6.0

Looking at diagnostic toolsets to capture video, image, audio, device status, measurements and sensor data

Session Data is Small [xml text]

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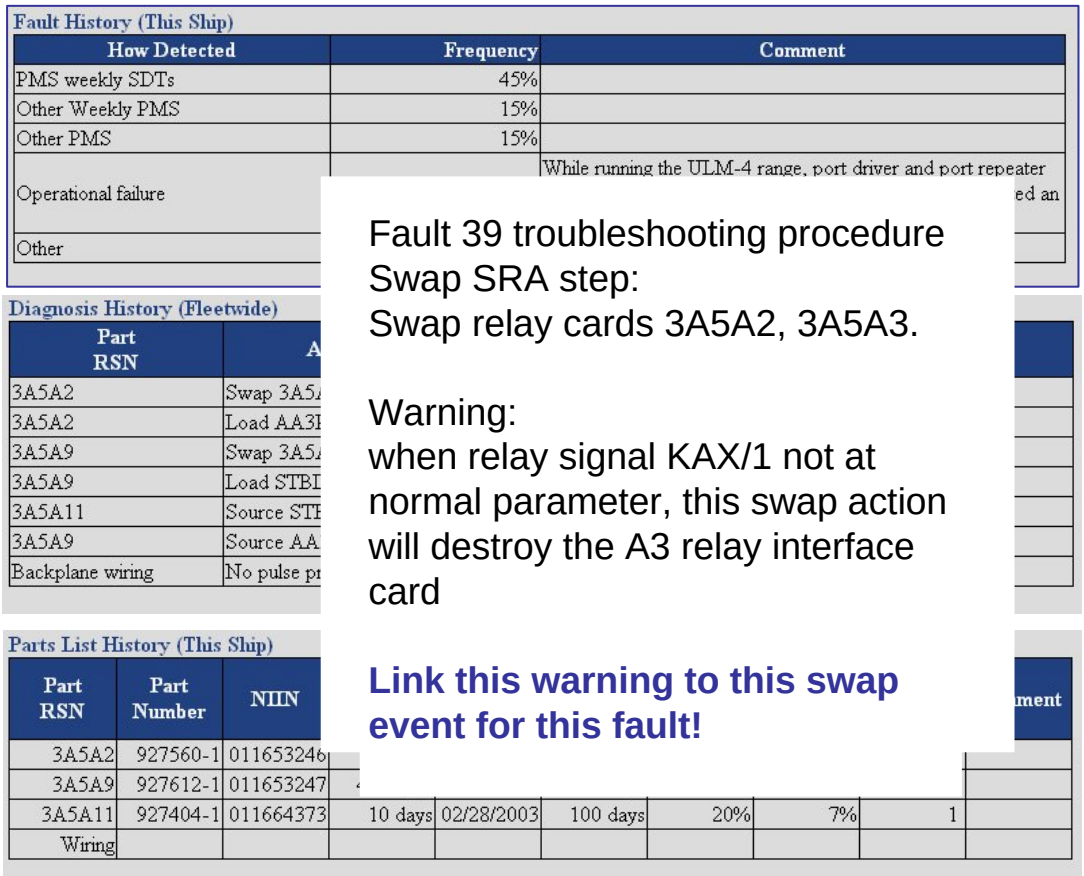
We Generate Knowledge



Fault History (This Ship)

How Detected	Frequency	Comment
PMS weekly SDTs	45%	
Other Weekly PMS	15%	
Other PMS	15%	
Operational failure		While running the ULM-4 range, port driver and port repeater ed an
Other		

Diagnosis History (Fleetwide)

Part RSN	A
3A5A2	Swap 3A5
3A5A2	Load AA3
3A5A9	Swap 3A5
3A5A9	Load STBI
3A5A11	Source ST
3A5A9	Source AA
Backplane wiring	No pulse pr

Parts List History (This Ship)

Part RSN	Part Number	NIIN							ıment
3A5A2	927560-1	011653246							
3A5A9	927612-1	011653247							
3A5A11	927404-1	011664373	10 days	02/28/2003	100 days	20%	7%	1	
Wiring									

Fault 39 troubleshooting procedure
Swap SRA step:
Swap relay cards 3A5A2, 3A5A3.

Warning:
when relay signal KAX/1 not at normal parameter, this swap action will destroy the A3 relay interface card

Link this warning to this swap event for this fault!

- ✓ Tracks and analyzes action flow, system state, system changes, resources used, observations, ….
- ✓ Mines recorded sessions to link valuable observations/experiences and actions
- ✓ Mines recorded sessions to discover knowledge about action sequences, failure relationships, and patterns
- ✓ Displays appropriate knowledge feedback to the sailor every step of the way
- ✓ Enables SMEs and engineers investigate session knowledge, with the goal of predictive and preventive maintenance
- ✓ Mining can be made real-time

Triggers … Failures … Actions … Parts… Relationships … Patterns … Root Causes …

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Knowledge Projection – Other Uses

- "The Fleet" doesn't have to be ships
  - Cars, trucks
  - Manufacturing equipment
  - *Any widely dispersed, long-life, capital intensive equipment with regular maintenance procedures !*
- Benefits
  - Documentation cost savings
  - Support for collaborative and remote troubleshooting
  - *Analysis of maintenance history across system lifecycle !*
- Do you see Knowledge Projection working for you?
  - ***Let us know !***

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