

Advanced Knowledge Provisioning Using Artificial Intelligence (AI) & Augmented Reality (AR) for Ship Repair Project

SDMT and BT Joint Panel Meeting

Alameda, CA

September 15, 2021



*Category B Data
Unlimited / Approved for Public Release*

Project Overview - Team

- Pacific Shipyards
- Conrad Shipyards
- Fincantieri Marine Systems, N.A.
- Auros Knowledge Systems
- D'Angelo Technologies
- Hepinstall Consulting Group
- NSRP Technical Manager
 - Jim House, ATI
- NSRP Project Technical Rep
 - Shawn Wilkerson, HII-Ingalls



Why the Focus on Ship Repair



“We don’t have enough (ship repair) capacity for peacetime,” let alone to repair combat-damaged ships during wartime.

First, Rear Adm. Eric Ver Hage
Commander of Navy Regional Maintenance Center (CNRMC)
and Director of Surface Ship Maintenance and Modernization

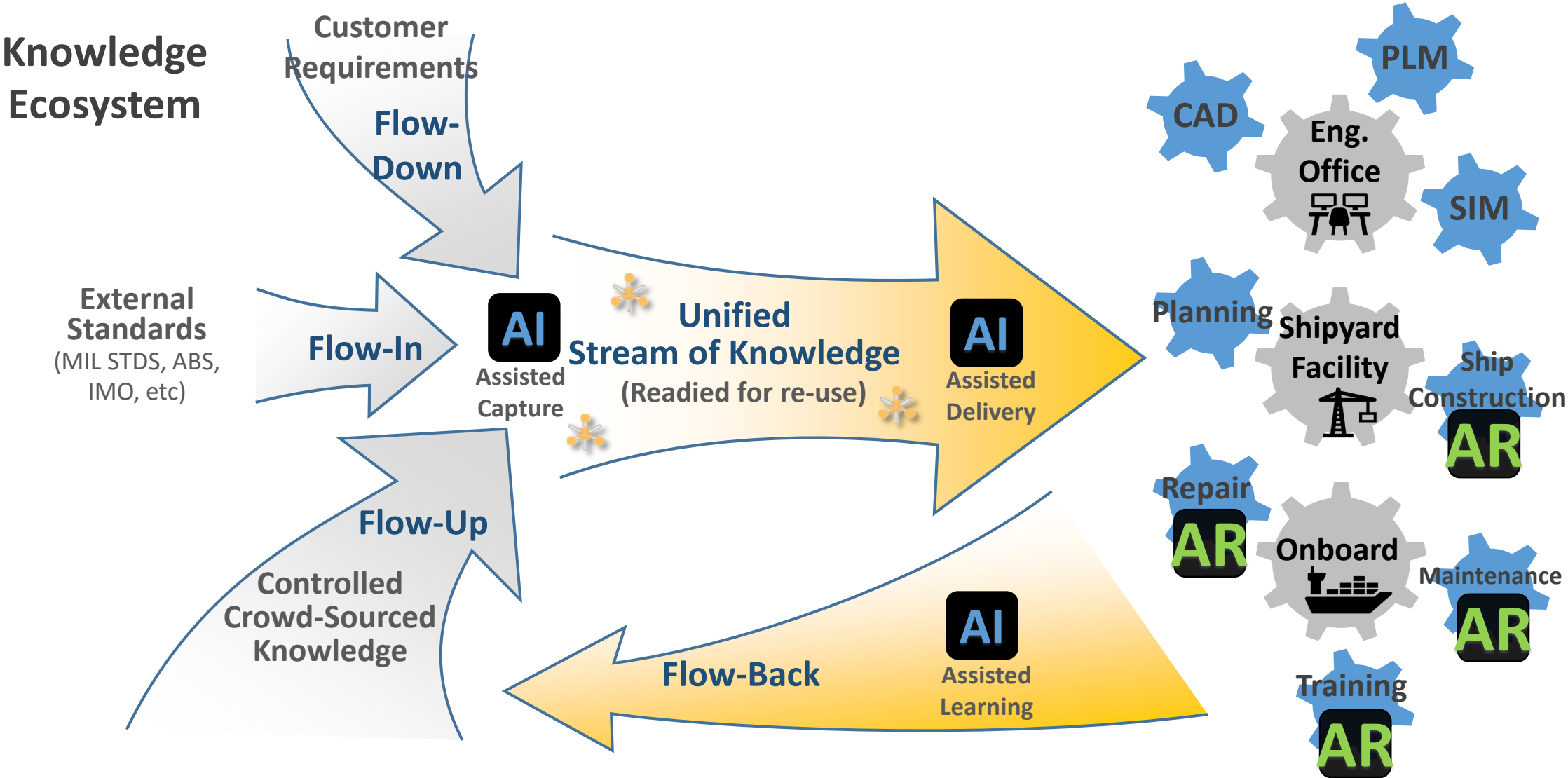
Aug 26, 2020, USNI News, [Lack of U.S. Warship Repair Capacity Worrying Navy](#)

Overall Project Objective



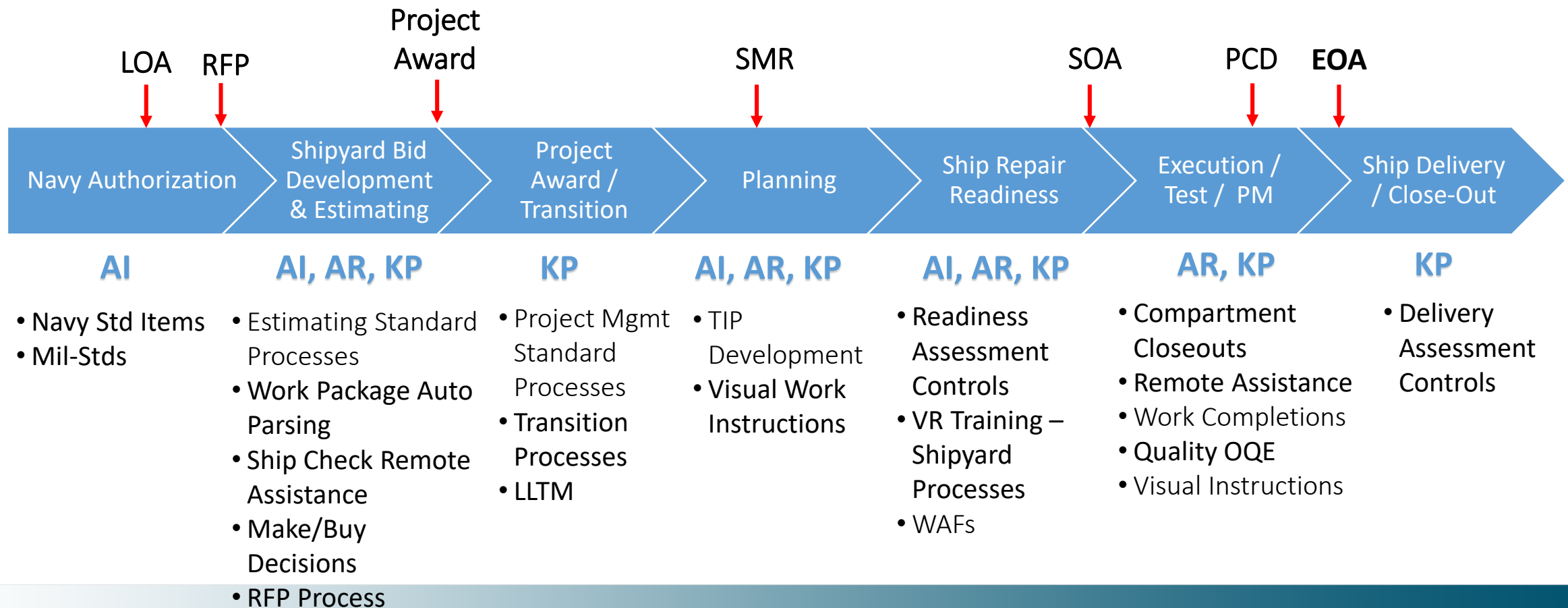
Automate the provisioning of critical knowledge directly into the ship repair workflows using Artificial Intelligence (AI) and Augmented Reality (AR)

Knowledge Operating System Vision

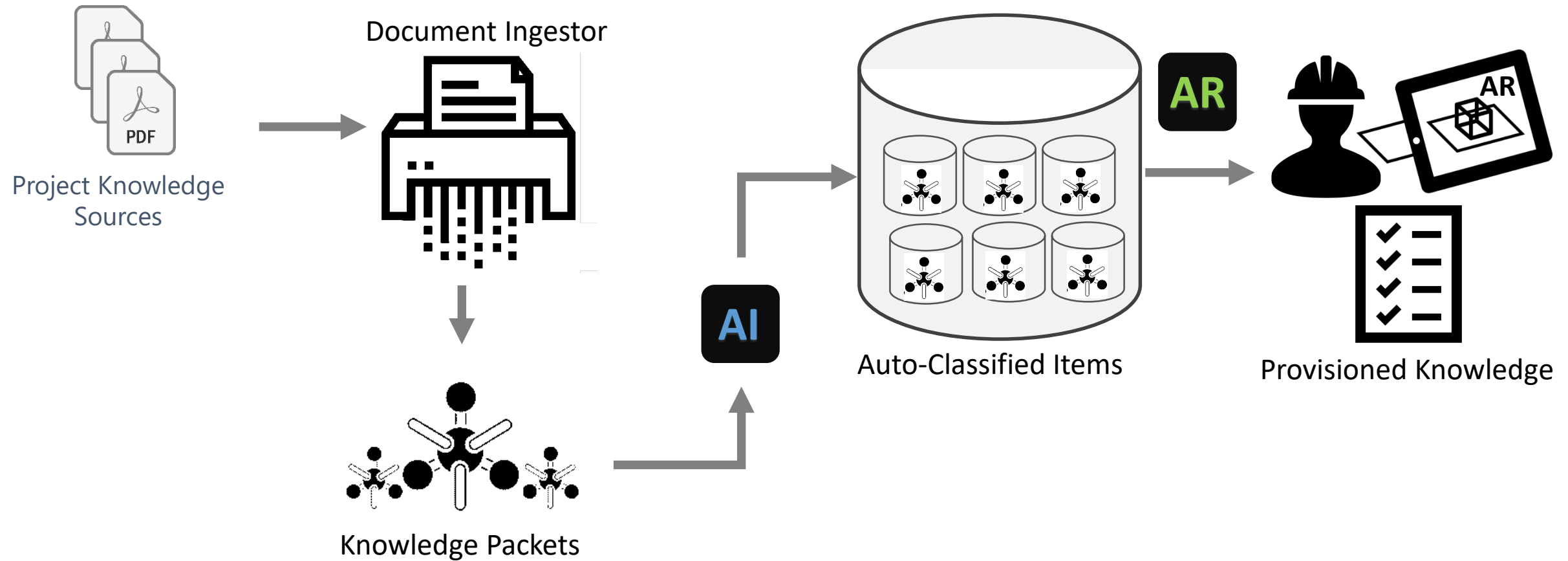


Why the Focus on Ship Repair

How can we use AI, AR, and Knowledge Provisioning technologies to reduce Maintenance Availability Lead Times and Cycle Times to **INCREASE CRITICAL SHIP REPAIR CAPACITY**



Applying AI and AR to Ship Repair



Artificial Intelligence Capabilities – Phase 1

- Development of core functionality
 1. Document parser
 2. Machine Learning based K-PAC Auto classifier (Auto tagging of K-PACs)
 - Design and prototype implementation of Machine Learning model
 - Proof Of Concept Results

The screenshot displays the 'Doc Ingestor Core Functionality' interface. On the left, the 'Parsing Cues Controls' panel includes a 'Parsing Cue Type' dropdown set to 'Heuristics' and an 'Add' button. Below this is a 'Parsing Cues Structure' tree with nodes for Header, Footer, Image Description, K-PAC EE, Heuristics, Section Boundary, and Section Boundary. A 'Parsing Cue Configuration' section provides instructions on using the selection tool and lists conditions for text selection. On the right, the 'PDF Controls' panel shows navigation buttons (Previous, Next), page information (Page: 9 / 308), and a 'Selection Tool' checkbox. The main area displays a PDF document with a table of contents and a list of sections. The 'Deadweight (DWT)' section is highlighted with a yellow box.

Parsing Cues Controls

Parsing Cue Type: **Heuristics** **Add**

Parsing Cues Structure

- Header
- Footer
- Image Description
- K-PAC EE
- Heuristics
- Section Boundary
 - Section Boundary
 - Section Boundary

Parsing Cue Configuration

Using selection tool, select the region in anypage where text would go as description of a K-PAC. Please make sure identified text meets following conditions

- It should be just plain text and does not contain any kind of equations or symbols.
- At least 2 lines of text should be included
- Each line shold be full i.e., it should start at left margin and end at the right margin of the page

PDF Controls

Previous **Next** Page: 9 / 308 **Go to** Selection Tool: ☐ K-PAC Selection Mode: ☐

Part 3 **Hull Construction and Equipment**
Chapter 1 **General**
Section 1 **Definitions** **3-1-1**

17 Displacement and Block Coefficient

17.1 Displacement
The displacement Δ , is the mass displacement of the craft in the design condition in metric tons (long tons), unless otherwise specifically noted.

17.3 Block Coefficient (C_b)
 C_b is the block coefficient obtained from the following equation:

$$C_b = \Delta / 1.025 L B_{\text{wet}} d \quad (\text{SI \& MKS units})$$
$$C_b = 35 \Delta / L B_{\text{wet}} d \quad (\text{US units})$$

where

Δ = molded displacement, as defined in 3-1-1/17.1
 L = scantling length, as defined in 3-1-1/3
 d = draft, as defined in 3-1-1/9
 B_{wet} = greatest molded breadth at the design load line

19 Gross Tonnage
The measurement of the internal volume of spaces within the craft as defined by the International Convention on Tonnage Measurement of Ships, 1969.

21 Deadweight (DWT)
For the purpose of these Rules, deadweight (DWT), is the difference, in metric tons (long tons), between the displacement of the craft at its summer load line or the craft with all tanks filled, maximum cargo loaded, maximum stores, and personnel or passengers and their effects on board, in water having a specific gravity of 1.025, and the unloaded weight of the craft. For the purpose of these Rules, the unloaded weight is the displacement of the craft, in metric tons (long tons), with no cargo, fuel, lubricating oil, ballast water, fresh water nor feed water in tanks, no consumable stores, and no personnel or passengers nor their effects.

23 Significant Wave Height
Significant wave height is the average height of the one-third highest observed wave heights over a given period.

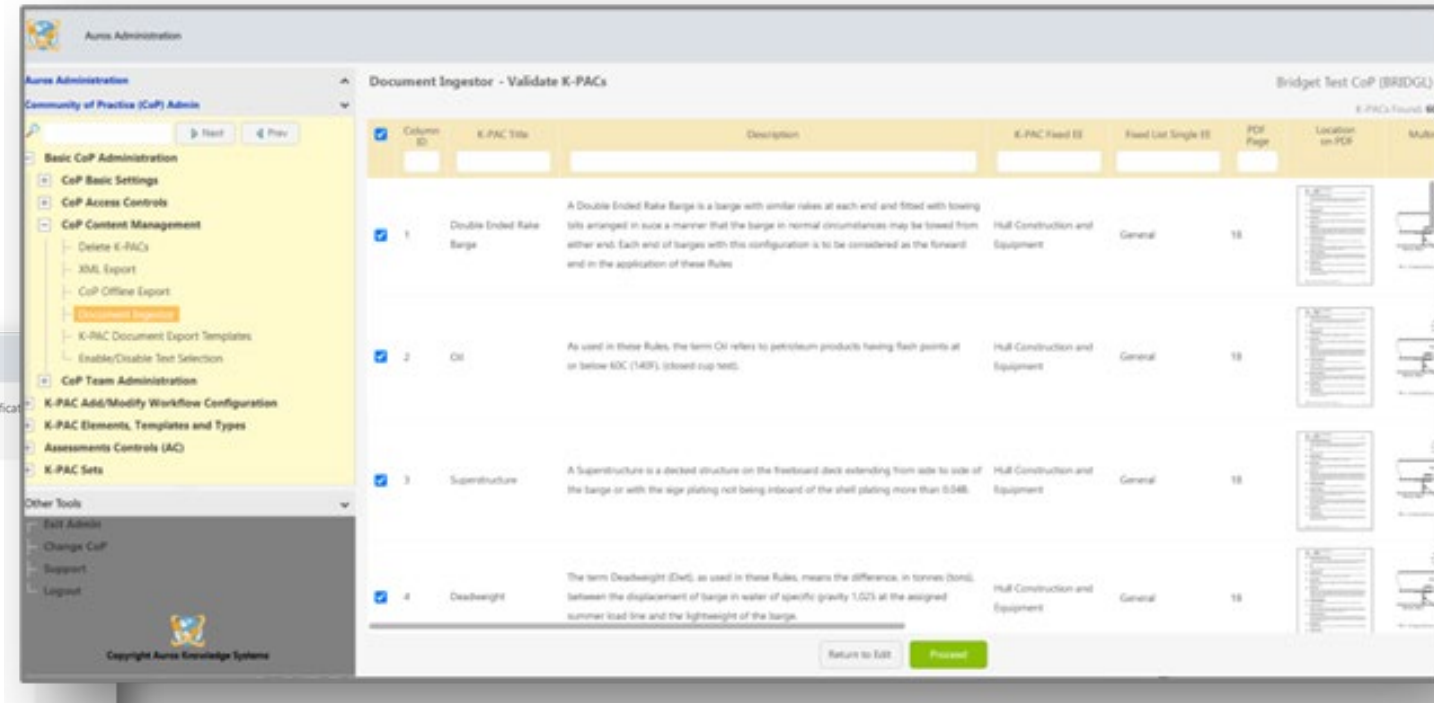
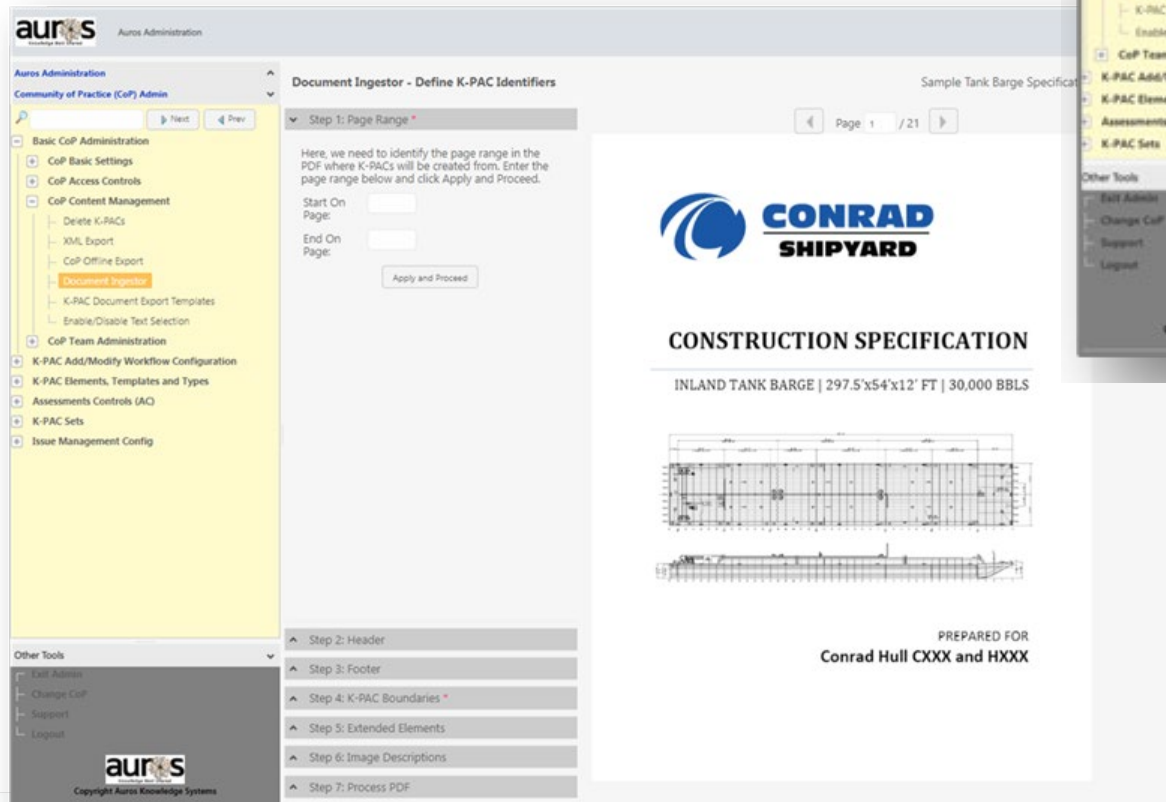
25 Speed
Speed is the design speed in knots with the craft running ahead at the maximum continuous rated shaft rpm and at the summer load waterline. Operational speed is 90% of design speed.

27 Rabbet Line (Fiber Reinforced Plastic)
The rabbet line is the line intersection between the outside of a craft's bottom and a craft's keel. Where there is no keel, the rabbet line is the bottom of the craft.

29 Administration
The government of the state whose flag the craft is intended to fly.

Artificial Intelligence Capabilities – Phase 2

- Develop User Interface for Document Ingestor
- Develop User Interface for AI Based K-PAC Classification Tool

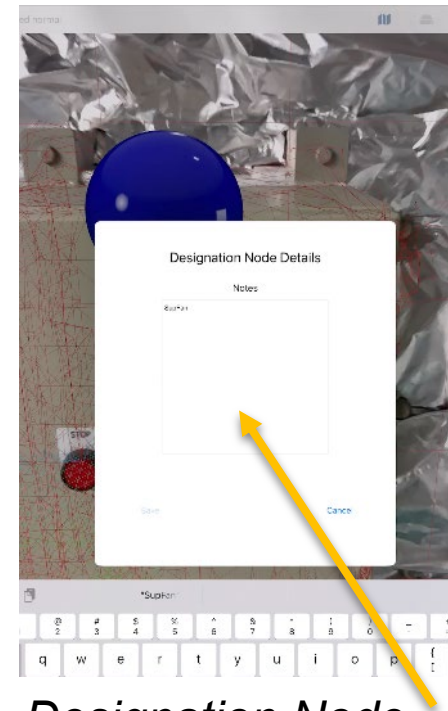
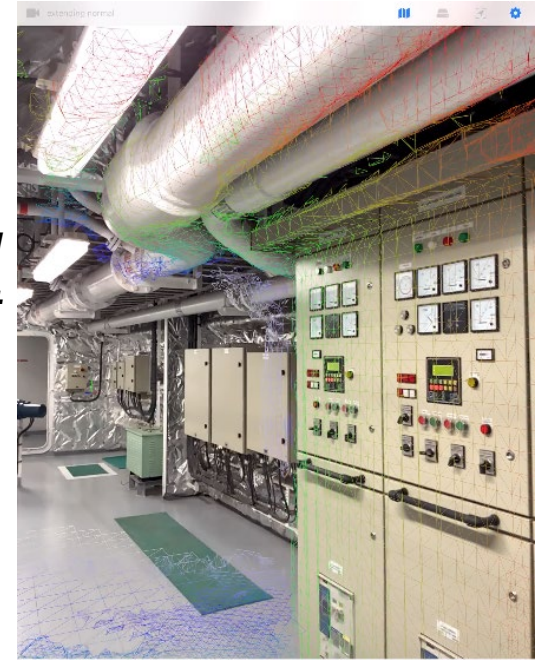


**AUROS AI Software Capabilities
Released in IQ8 – August 2021**

Augmented Reality Features

- Allows for information to be linked to specific ship compartments
- Scanning
 - iPad cameras make a model of the physical compartment
 - Model becomes point of reference for virtual content placement
 - Scanning facilitates automatic and accurate placement of virtual content
- Designation Nodes
 - Saved in association with the ship compartment
 - Stores text relating to any physical objects nearby
 - Stored information is dynamic
- Doorways
 - Simplify transitioning between virtual content
 - Facilitate offline Navigation

View of a scanned compartment area



Designation Node Information Text Box

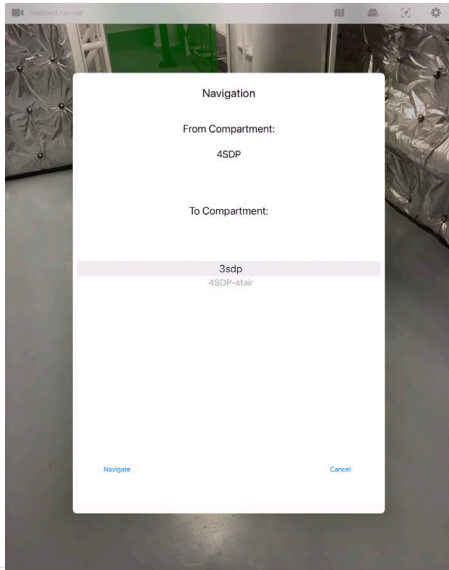


Doorway

Augmented Reality Features

- Navigation

- Turn-by-turn directional system
- Provides directions from current Compartment to any other scanned Compartment
- Does not require internet, Bluetooth, or Location Services/GPS
- Virtual arrow points user toward the entrance to the next compartment



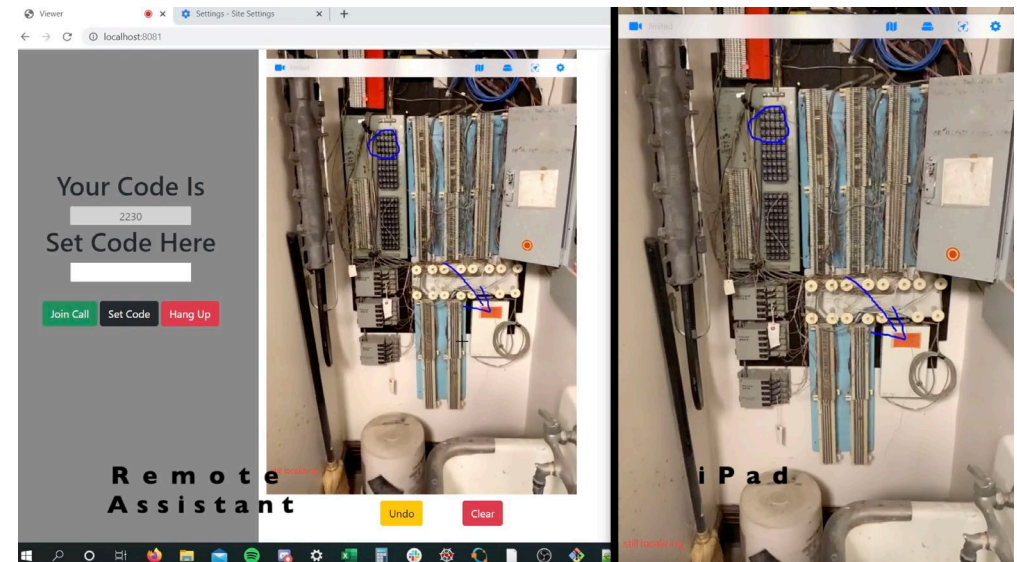
Compartment Selection



Active Navigation Arrow

- Remote Assistance

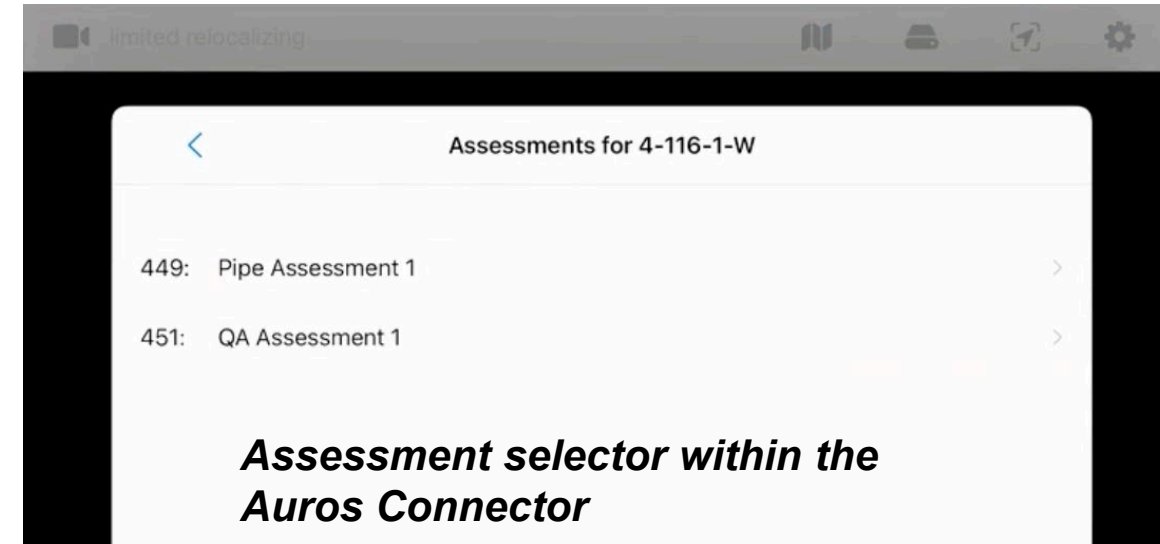
- Supports more effective assistance for workers from off-site SMEs
 - Direct, peer-to-peer connection
 - Real-time communication
- Companion web client for use by SME
 - Video feed of iPad screen visible for SME
 - Two-way audio communication
 - Drawing feature



Split view of web client and iPad screen

Augmented Reality Features

- Auros Connector
 - Gives worker access to provisioned knowledge and reference materials
 - Live adjustment to work item conformance states
 - Built-in file viewer
 - Compartment-specific content
 - Data preload feature allows Auros Connector to function with poor network connection



Phase 2 Improvements

Improved user interface and experience
Optimized, Enhanced, Simplified

Shipyard Pilots

Shipyard Pilots - PSI



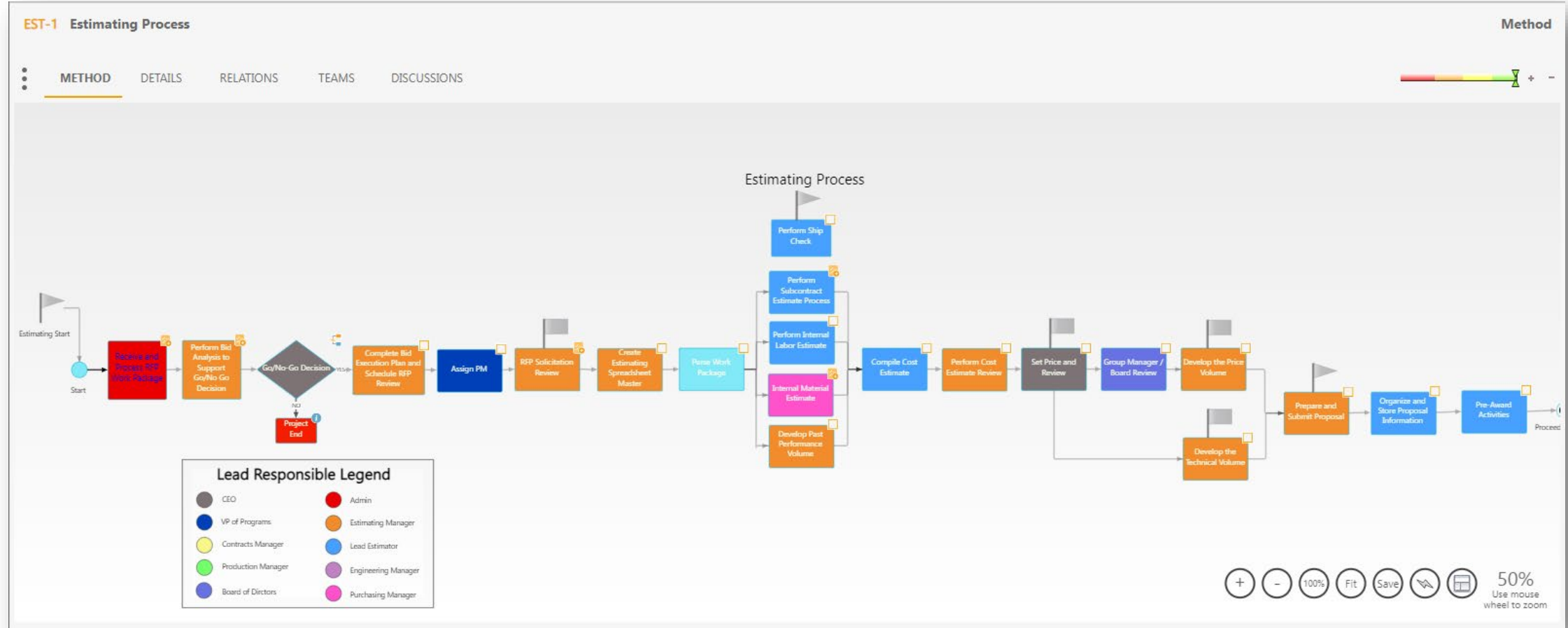
Estimating

Planning

Project
Management

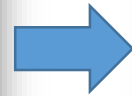
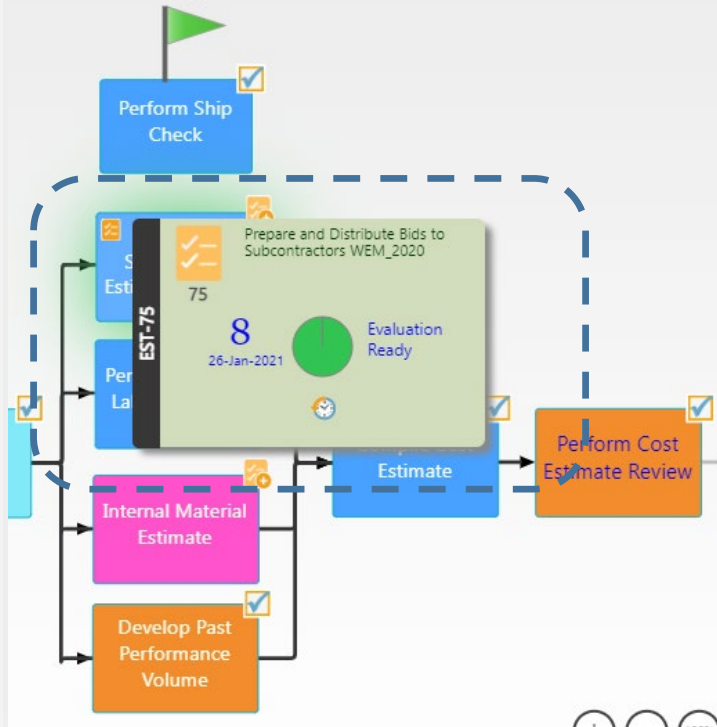
Production

Quality



- Navy MACMO level estimating process and standard work captured
- Shared workflow with roles and responsibilities clearly identified

Estimating Process



WEM_2020

Options Issues Reports Filter Views View Options No Grouping Set Defaults

Prepare and Distribute Bids to Subcontractors

Conformance State	K-PAC ID	Status Icons	K-PAC Title	Description	Explanation	Support Document	LineItem Attach
NE Red Yellow Green NA	EST-26	V1	Create the Email body to specify the WTs to bid, POP, and RFQ Due Date	Create the Email body Email a narrative that specifies standard information to include in the email to subcontractors inviting them to bid. 1. Obtain Period of Performance and Subcontractor RFQ Due Date from Lead Estimator. 2. Use the Subcontractor RFQ Email Template to create Project Specific Email. (See Support Documents) - Use the Subcontract Quote List to identify specific work items and paragraphs for each subcontractor. - Access Subcontract File on X drive to identify Point of Contact Information for each vendor/subcontractor - Create standard List of Deliverables - Request for Exclusions 3. Create RFP Email for each subcontractor.	The distributor will undergo, and must pass, waterproofness test. The component shall be submerged in tapwater, with the component uppermost surface a minimum of one inch below the surface of the water. The component shall be checked for leaks, there shall be no bubbles escaping from the interior of the component when the test chamber is evacuated to a pressure six pounds below atmospheric by applying 6 psi internal pressure for one minute while submerged.	Subcontractor RFQ Email Template.docx	0.0 View
NE Red Yellow Green NA	EST-33	V1	Determine distribution method ie SAFE, email, ect	Determine distribution method (ie SAFE, email, etc) If there are export/ITAR controlled requirements, the Subcontract RFP Package has to be emailed using the SAFE environment. (Find out from PSI who does this and how is this performed). Also - does it make sense to always communicate through SAFE during the bid process since it's business sensitive?	The class I distributor, including distributor shaft to crankshaft coupling, will operate for 600 hours with no maintenance except resetting of breaker points at 100 hour intervals, and lubrication of breaker cam, breaker lever pivot and felt wick under rotor. Subsequently, the distributor assembly must operate as specified in 3.5.1 and 3.5.2		0.0 View
NE Red Yellow Green NA	EST-30	V1	List of Required Subcontractor RFQ Deliverables	List of Deliverables: - PSI Bid sheet - Request for exclusions - List of support services required by Work Item. (Support Services Request by Work Item) - Laydown requirements? (Laydown Requirements Template) - Proposed Schedule Note: Click on the K-PAC ID link to the left to open the K-PAC Details view. Once opened, see Support Documents chapter for template This list provides a checklist of other requirements that the subcontractor will be expected to meet if they are selected for award. Demonstrate Support, Control/ITAR Controls are in place, if applicable.	The distributor will be operated and must conform to either 3.5.4.1 or 3.5.4.2 as applicable (see 4.10.6).	PSI RFQ Bid Sheet-R1.xlsx List of Support Services-R1.xlsx Subcontractor Proposed Schedule.xlsx	0.0 View

- Provisioned knowledge is utilized and evaluated resulting in effective knowledge transfer and visibility of project health

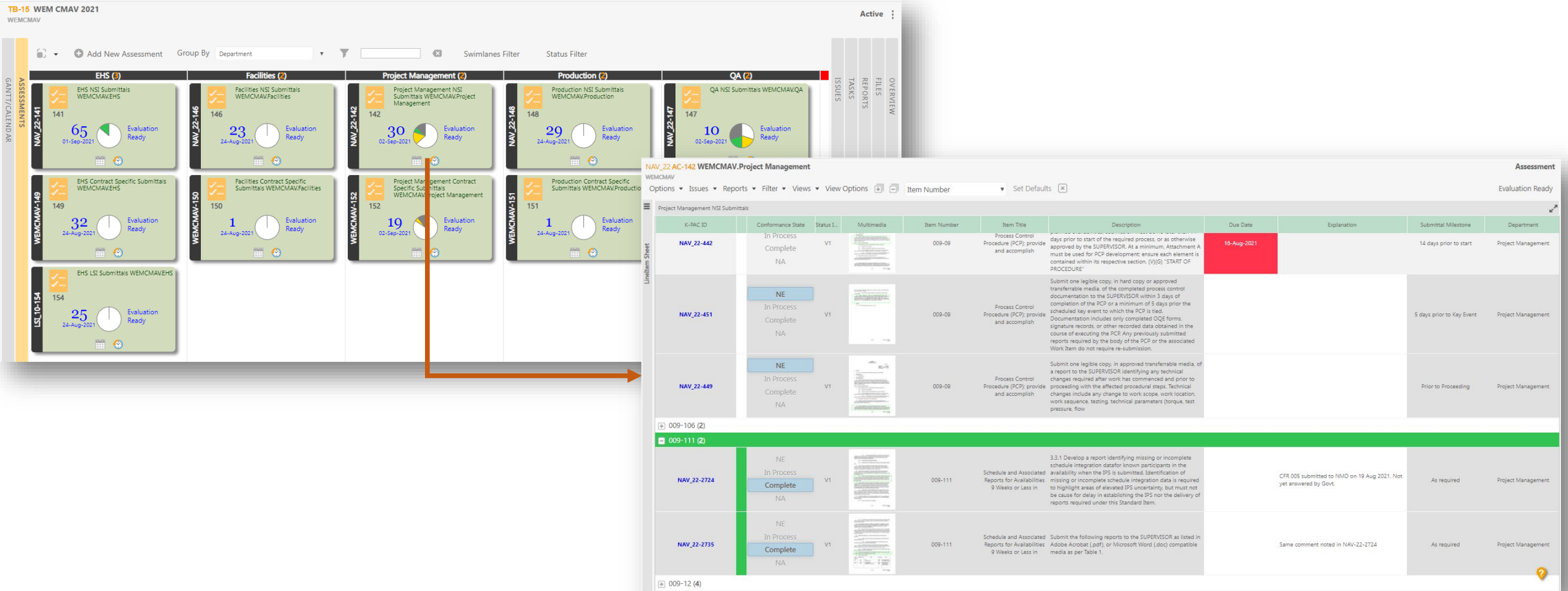
Estimating

Planning

Project
Management

Production

Quality



- Project Submittal Tracking Dashboard / Assessment

Shipyard Pilots – FMSNA

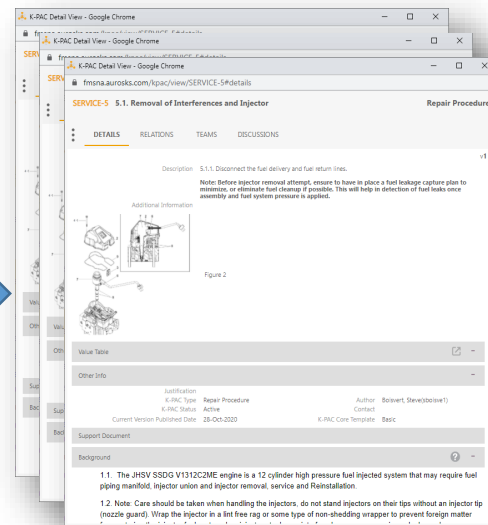


Maintenance and
Repair Procedures

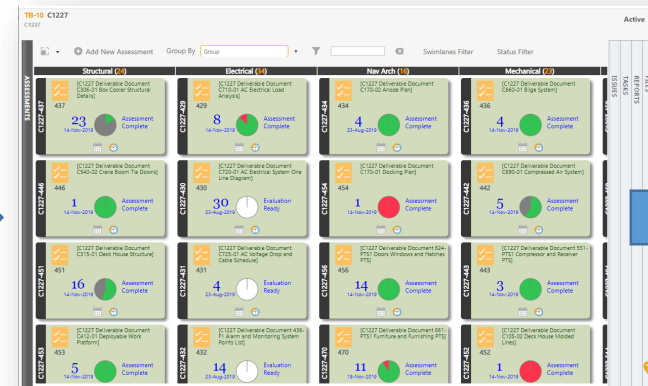
Maintenance Procedures - High Level Process Summary



**1. Technical
Documentation**



**2. Technical
documentation converted
into Knowledge Packets**



**3. Procedure level
Assessment Controls
created to track status**



**4. Procedure level
Assessment Controls
delivered at point of
need**

FMSNA Use Case – Service Job Execution

<p style="text-align: right;">Fincantieri Marine Systems North America 36 SS 6V-AM Overhaul Manual</p>																																			
Chapter 7 Under Head and Running Gear Assembly																																			
<h2 style="margin: 0;">Assembly Quality Assurance Report</h2>																																			
<p>DISTRIBUTION STATEMENT D:</p> <p>Distribution authorized to DOD components and DOD contractors only. Critical Technology May 2020. Other requests for this document shall be referred to Naval Sea Systems Command (SEA 04R3M). Destroy by any method that will prevent disclosure of contents or reconstruction of the document.</p>																																			
<table style="width: 100%; border-top: 1px solid black; border-bottom: 1px solid black;"> <tr> <td style="width: 15%;">Date: May 2020</td> <td style="width: 15%;">NIP Serial: 3112</td> <td style="width: 15%;">MRC: 30 FDFY Y</td> <td colspan="3" style="width: 40%;">Periodicity: A++</td> </tr> </table>						Date: May 2020	NIP Serial: 3112	MRC: 30 FDFY Y	Periodicity: A++																										
Date: May 2020	NIP Serial: 3112	MRC: 30 FDFY Y	Periodicity: A++																																
<table style="width: 100%; border-top: 1px solid black; border-bottom: 1px solid black;"> <tr> <td colspan="6">Locations:</td> </tr> <tr> <td style="width: 15%;">Ship System:</td> <td colspan="5">Electric Power Generation 31000</td> </tr> <tr> <td>System:</td> <td colspan="5">Ship Service Power Generation 31100</td> </tr> <tr> <td>Subsystem:</td> <td colspan="5">Generator Set, Ship Service Diesel 31120</td> </tr> <tr> <td>Equipment:</td> <td colspan="5">Generator Set, Ship Service Diesel</td> </tr> </table>						Locations:						Ship System:	Electric Power Generation 31000					System:	Ship Service Power Generation 31100					Subsystem:	Generator Set, Ship Service Diesel 31120					Equipment:	Generator Set, Ship Service Diesel				
Locations:																																			
Ship System:	Electric Power Generation 31000																																		
System:	Ship Service Power Generation 31100																																		
Subsystem:	Generator Set, Ship Service Diesel 31120																																		
Equipment:	Generator Set, Ship Service Diesel																																		
<table style="width: 100%; border-top: 1px solid black; border-bottom: 1px solid black;"> <tr> <td style="width: 15%;">Rate:</td> <td style="width: 15%;">Man-Hours:</td> <td style="width: 15%;">Rate:</td> <td style="width: 15%;">Man-Hours:</td> <td style="width: 15%;">Rate:</td> <td style="width: 15%;">Man-Hours:</td> </tr> <tr> <td>R03</td> <td>0.5</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>Total Man-Hours:</td> <td>0.5</td> <td>Elapsed Time:</td> <td>0.5</td> <td></td> <td></td> </tr> </table>						Rate:	Man-Hours:	Rate:	Man-Hours:	Rate:	Man-Hours:	R03	0.5					Total Man-Hours:	0.5	Elapsed Time:	0.5														
Rate:	Man-Hours:	Rate:	Man-Hours:	Rate:	Man-Hours:																														
R03	0.5																																		
Total Man-Hours:	0.5	Elapsed Time:	0.5																																
<p>MAINTENANCE REQUIREMENT DEFINITION</p> <p>1. <u>Cable and Inspect Interse Air Filter</u></p>																																			
<p>SAFETY PRECAUTIONS</p> <ol style="list-style-type: none"> 1. Before start comply with Navy Safety and Occupational Health (SOH) Program 5100.19 series; share activities comply with SOH Program Manual, OPNAVINST 5100.19 series; safety procedures shall be in accordance with the set instruction. 2. To personal protective injury, Tag-Out procedure shall be in accordance with the set instruction. 3. Avoid repeated prolonged skin contact with hazardous materials. Wash affected skin prior to eating, drinking, smoking, or applying cosmetics. 4. Personnel and bearing protection devices must be worn, and immediate area de-Equipments (PPE) when using vibrating low frequency/high-pressure air. 																																			
<p>TOOLS, PARTS, MATERIALS, TEST EQUIPMENT</p> <p>MATERIALS</p> <ol style="list-style-type: none"> 1. [0000]Grease, general purpose, MIL-C-16791 1. [0000]Random Material User's Guide (DOLUG Group 3) 1. [0000]Maintenance kit, spares 1. [0144]Tag, safety 1. [0150]Gasket, silicon seal instrument, MIL-PRF-27617.TV III 1. [0000]Random Material User's Guide (DOLUG Group 13) 1. [0110]Wrench set 1. [0274]Fuel, white, J galon 1. [0274]Water, fresh, No X321 - W provide 																																			
<p>PARTS</p> <ol style="list-style-type: none"> 1. [1800]Filter (Contingency) 																																			
<p>TOOLS</p> <ol style="list-style-type: none"> 1. [0040]Wrench set, combination box end open, metric, 12mm to 32mm 1. [0110]Ham, set 1. [1440]Brush, scrub 																																			
<p>MISCELLANEOUS</p> <ol style="list-style-type: none"> 1. [0040]Personal, industrial 1. [0040]Flow, water, No X321 - WC provide 1. [0040]Flow, waste, no service, WC provide 1. [0170]Jockey, industrial, non-vented 1. [0440]Air pressure test, 100 PSI 1. [1100]Random Material User's Guide (DOLUG), 5086-WC-STM-420-02ST 1. [1240]AAO-AID-TSM-01/TM, TAG OUT OF THE 3AERICAL 1. [1704]Gloves, 4-mil Nitrile, Light tone only 																																			
<p>Maintenance Requirement Card (IRC) Page 1 of 3</p> <p>OPNAV 4710.18 (REV. 1-97)</p>																																			

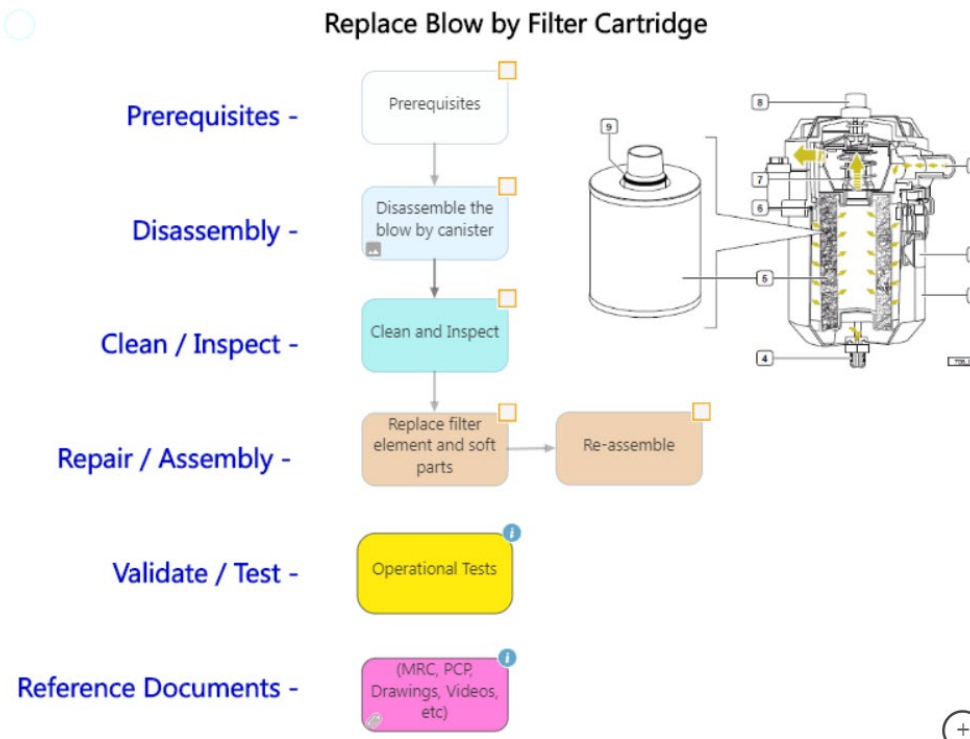
FMNA COVER SHEET JHSV FORMAL WORK PACKAGE (FWP)	
Port Engineer: Contract Number: Ship Name & Hull Number: Description: 1000 H Maintenance	Port engineer Phone Number: Job Code:
Category: <input checked="" type="checkbox"/> PMS <input type="checkbox"/> WARRANTY WORK <input type="checkbox"/> OEM RETROFIT	
Date Work Scheduled to Begin: Document or Reason for Late Authorization of work: (If authorized within 1 days of scheduled work)	
Technical Manager Reviewed and Approved: Name: _____ Date: _____	
Sub-Contractor Reviewed and Approved by: (If Required) Name: _____ Date: _____	
Remarks or CFR:	

Section 2:

<p>LEAD TECHNICIANS</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p>	<p>MECHANICS</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p>
---	--

BASELINE

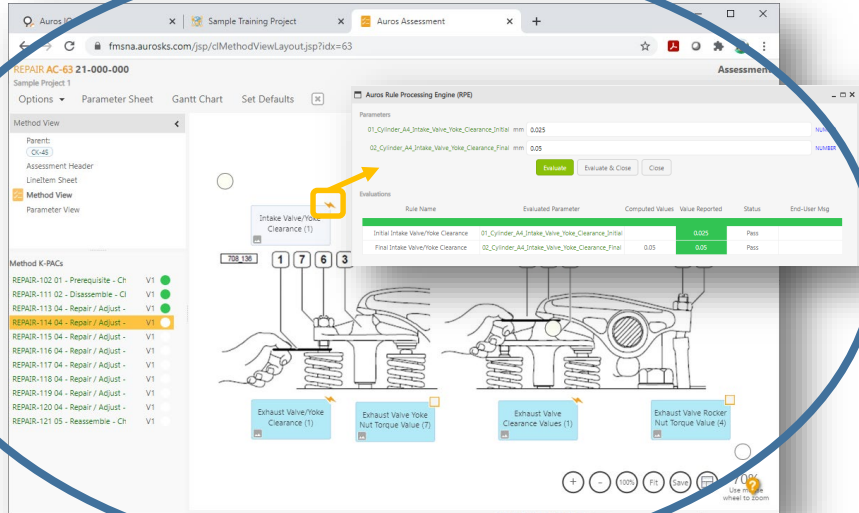
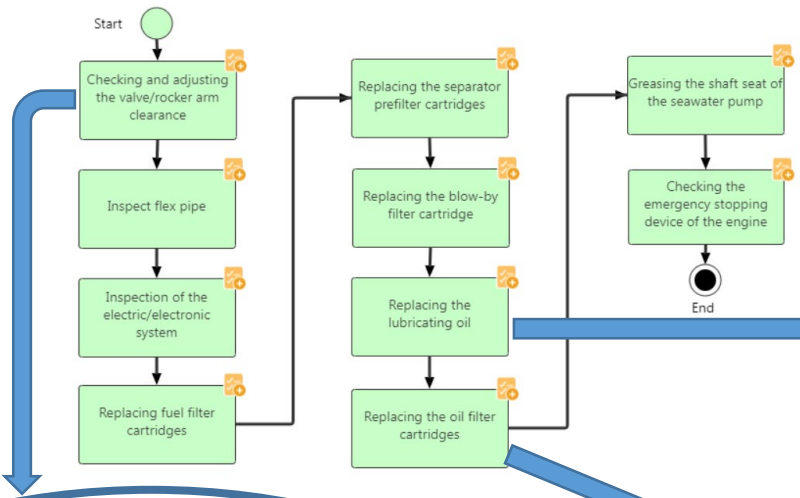
- **Many manually derived documents in various locations**
- **Mechanics burdened to know all information**
- **Knowledge gaps within workflow**
- **Difficult change control**

**AUROS**

- **All job information in one system**
- **Integral work-flow**
- **Easy to use graphical interface**
- **Easy to monitor progress and compliance**
- **Information & data available on-demand**
- **Databased / easy change control**

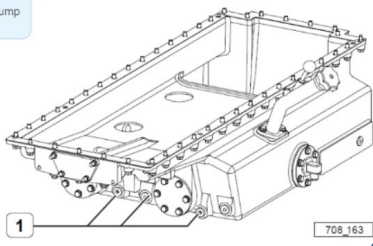
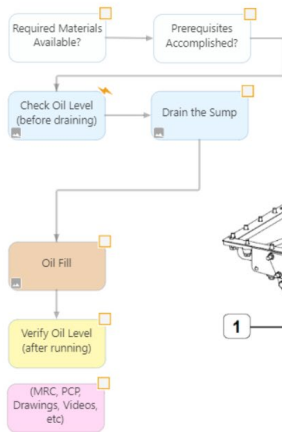
Preventative Maintenance Procedures

1000 Hour Maintenance Procedure



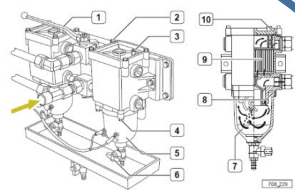
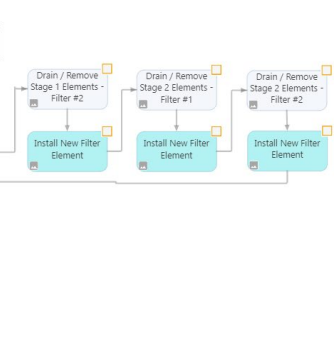
Replace the Engine Oil

- Prerequisites -
- Disassembly -
- Clean / Inspect -
- Repair / Assembly -
- Validate / Test -
- Reference Documents -



Replace Elements in Stage 1 & 2 Fuel Filters / Water Separator

- Prerequisites -
- Disassembly -
- Clean / Inspect -
- Repair / Assembly -
- Validate / Test -
- Reference Documents -

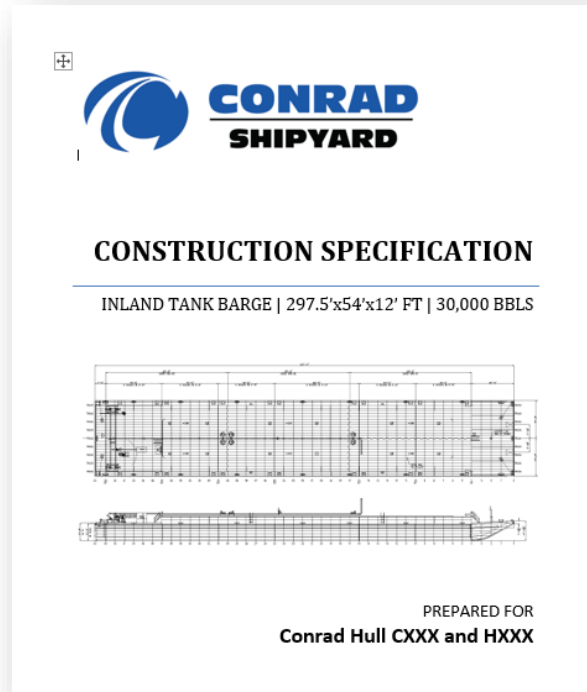


Shipyard Pilots – Conrad Shipyard

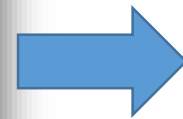


Specification
Compliance

Legacy Specification Compliance Process



Specification Documentation

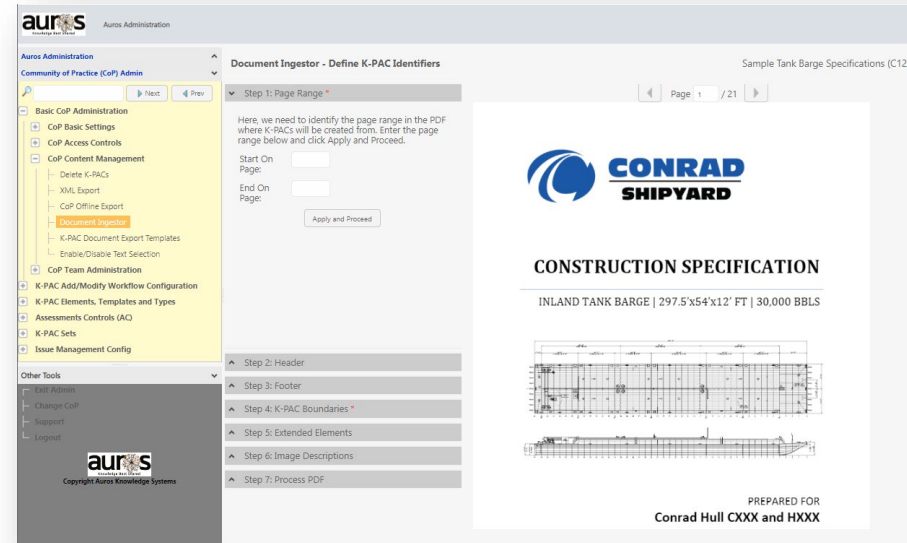
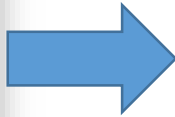
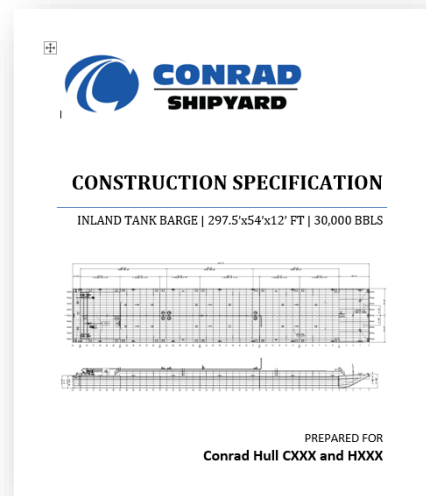


SWBS	SWBS Description	Requirements or Specification Section	Requirements or Specification Title	Requirements or Specification Description
050	Ship System Performance	050	VESSEL DESCRIPTION & PRINCIPAL CHARACTERISTICS	Engine Lube Oil 1,200
050	Ship System Performance	050	VESSEL DESCRIPTION & PRINCIPAL CHARACTERISTICS	Gear Oil 800
050	Ship System Performance	050	VESSEL DESCRIPTION & PRINCIPAL CHARACTERISTICS	The tank capacities above are the total available volume of the tank spaces arranged in the vessel hold, assuming a permeability of 98.5%.
050	Ship System Performance	050	VESSEL DESCRIPTION & PRINCIPAL CHARACTERISTICS	The main deck house shall be segregated longitudinally by a watertight bulkhead with a multi-dogged watertight door installed. Forward of the segregating bulkhead will be living space which will contain: forward deck stores space, galley and mess with walk-in pantry, exercise room, engineer's stateroom with private head adjacent to engineer's office (abutting segregating bulkhead), crew lounge, interior access to the upper deck, one (1) full common access head, laundry room. Aft of the segregating bulkhead will be working areas which will include: upper engine room, paint locker (access from exterior), generator room and steering gear room.
050	Ship System Performance	050	VESSEL DESCRIPTION & PRINCIPAL CHARACTERISTICS	The upper deck house shall contain staterooms for nine (9) crew, including deck crew members, the cook and junior officers. Crew staterooms shall each contain two (2) berths with shared heads. Junior officer staterooms shall each contain one (1) berth with private head. In multiple capacity staterooms, efforts shall be taken to avoid stacked bunks in favor of twin beds.
050	Ship System Performance	050	VESSEL DESCRIPTION & PRINCIPAL CHARACTERISTICS	The Texas deck house shall contain staterooms for no less than three (3) senior officers, junior officers and guest. The Texas deck will also contain a large Electronics locker, which shall be climate controlled. Staterooms shall each contain one (1) berth with private head. In multiple capacity staterooms, efforts shall be taken to avoid stacked bunks in favor of twin beds.
050	Ship System Performance	050	VESSEL DESCRIPTION & PRINCIPAL CHARACTERISTICS	The pilothouse shall be multi-sided (at least hexagonal) raised type to provide for a maximum line of sight for pilothouse personnel of approximately 35'-0" above the design waterline. The pilothouse shall be fitted with a suitable toilet arrangement, and wash basin. The pilothouse shall contain all necessary controls and navigational aids necessary for efficient operation of the vessel. Highest fixed point shall be approximately 45'-0" above design waterline (antennas, etc., will be designed to be folded down, as necessary).
050	Ship System Performance	050	VESSEL DESCRIPTION & PRINCIPAL CHARACTERISTICS	The principle dimensions of the vessel shall be: Principle Dimension (Feet - inches) Length, molded 366'-0" Beam, molded 48'-0" Depth, molded at CL, midships 12'-4" Depth, molded at side, midships 12'-0" Draft, full load (maximum) 10'-6" Draft, light operational load 9'-0" The vessel shall be designed and built in accordance with: I Current U.S.C.G. rules as applicable, as well as all regulations incorporated by reference. I U.S.C.G. Subchapter M for vessels towing hazardous cargoes. I Design and construction, but not classed in accordance with (but not classified to) current latest edition of American Bureau of Shipping "Rules for Building and Classing Steel Vessels for Service on Rivers and Inland Waterways" as if to be classed "A1" Towboat, River and Inland Coastal Waterway Service. I The major machinery shall be Type approved, however, ABS certificates are not provided.
070	General Requirements for Design & Construction	070	GENERAL REQUIREMENTS FOR DESIGN & CONSTRUCTION	
070	General Requirements for Design & Construction	070	GENERAL REQUIREMENTS FOR DESIGN & CONSTRUCTION	
070	General Requirements for Design & Construction	070	GENERAL REQUIREMENTS FOR DESIGN & CONSTRUCTION	
070	General Requirements for Design & Construction	070	GENERAL REQUIREMENTS FOR DESIGN & CONSTRUCTION	

Manually created XLS files to track compliance

Specification Compliance

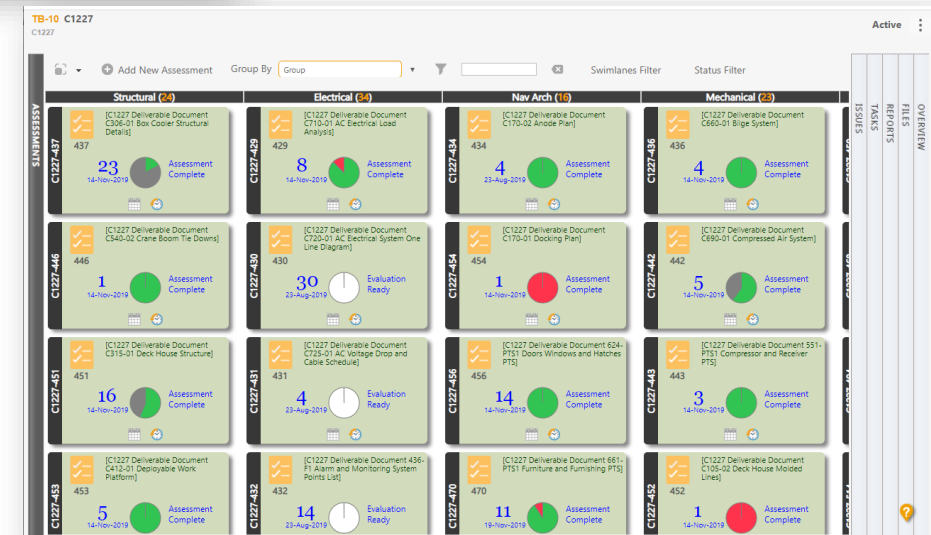
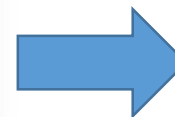
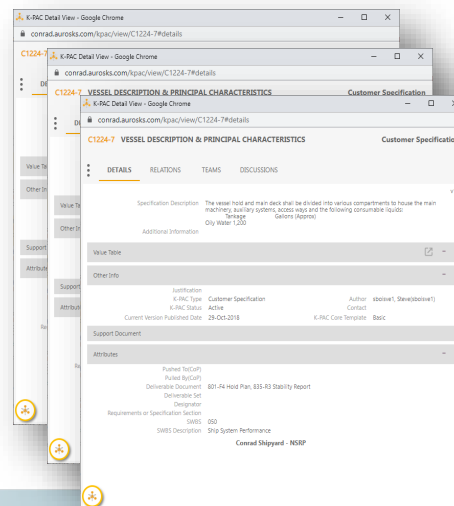
Automated Specification Compliance Process Summary



2. Auros Document Ingestor with AI capabilities to Automatically Parse and categorize specifications

1. Specification Documentation

3. Specification Documentation converted into Knowledge Packets



4. Assessment Controls to track compliance across deliverables

Final Steps

- Finish Implementation Pilots at Shipyards and Collect Data (June 2021 – September 2021)
 - Shipyard Implementation Report
- Measure Effectiveness of Shipyard Pilots (Aug – Sept 2021)
 - Implementation Evaluation Summary Report
- Conduct Final Project Workshop (Oct 2021)
 - Final Project Workshop Report
- Deliver Final Project Report (Oct 2021)
 - Final Project Report



WORKSHOP
DATE: TBD
Stay tuned!

AI/AR Knowledge Provisioning



Questions