Building “Failure Data & Prediction Models” for Ship Construction & Sustainment Support

NSRP Joint Panel Meeting
RA Project Presentation
August 20-21, 2024, Vancouver, BC
Presenters:
Subrat Nanda; ABS
Mark Debbink; HII-Newport News Shipbuilding

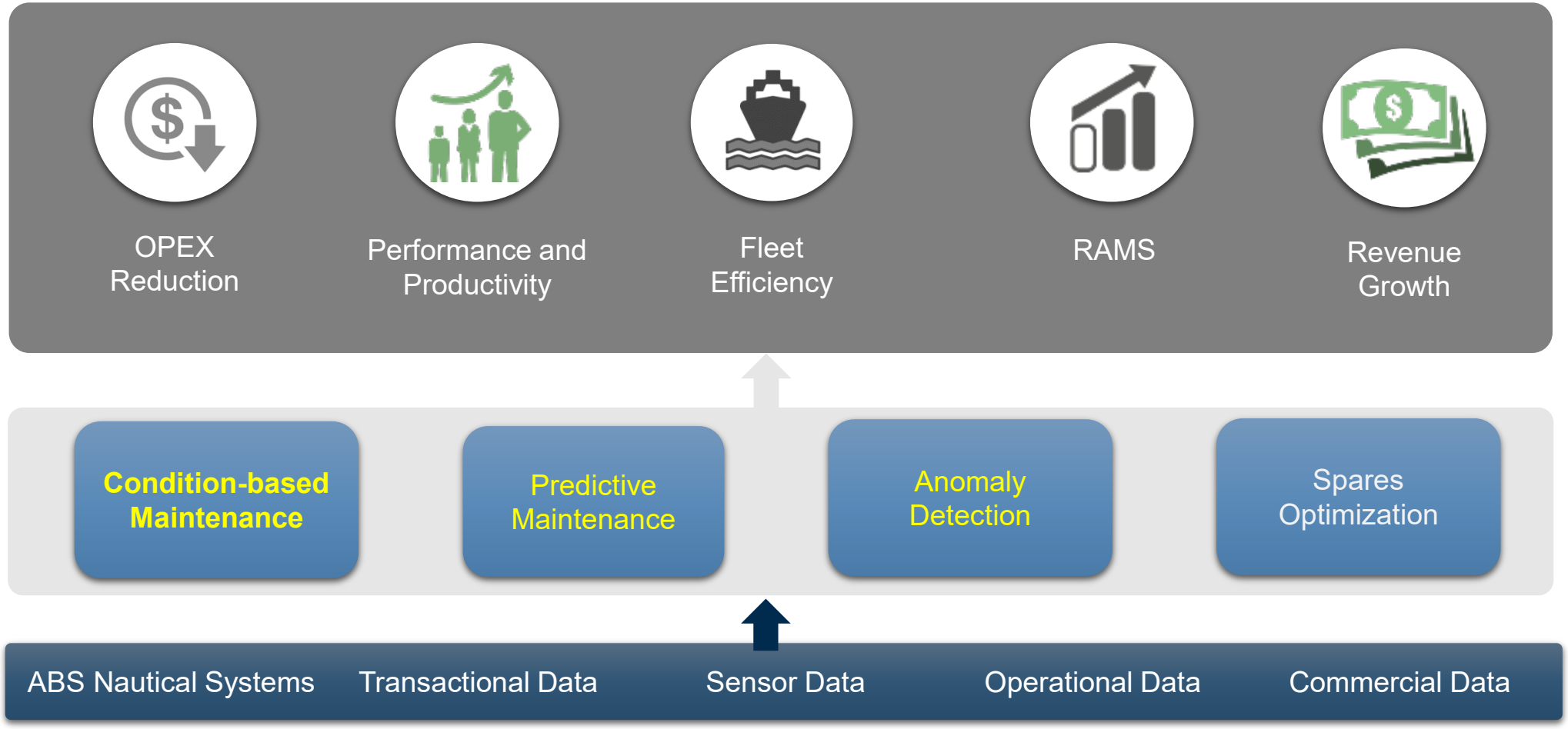
Project Overview

- Prime/Lead:
  - American Bureau of Shipping (ABS
- Team Members:
  - Newport News Shipbuilding (HII-NNS)
  - Ingalls Shipbuilding (HII-Ingalls)
- Government Participants:
  - NAVSEA 05Z with NSWC Philadelphia & USCG Surface Forces Logistics Center
  - NOAA, MSC
- Duration
  - 18 months, 2 phases with go-no/go review
- NSRP RA Project 2024-01

Subrat Nanda; Chief Data Scientist

- Joined ABS in Jan 2018
- 20+ years of Industrial AI experience
- Artificial Intelligence | Machine Learning | Prognostics & Health Management | Statistical & Risk Modelling | Digital Twins

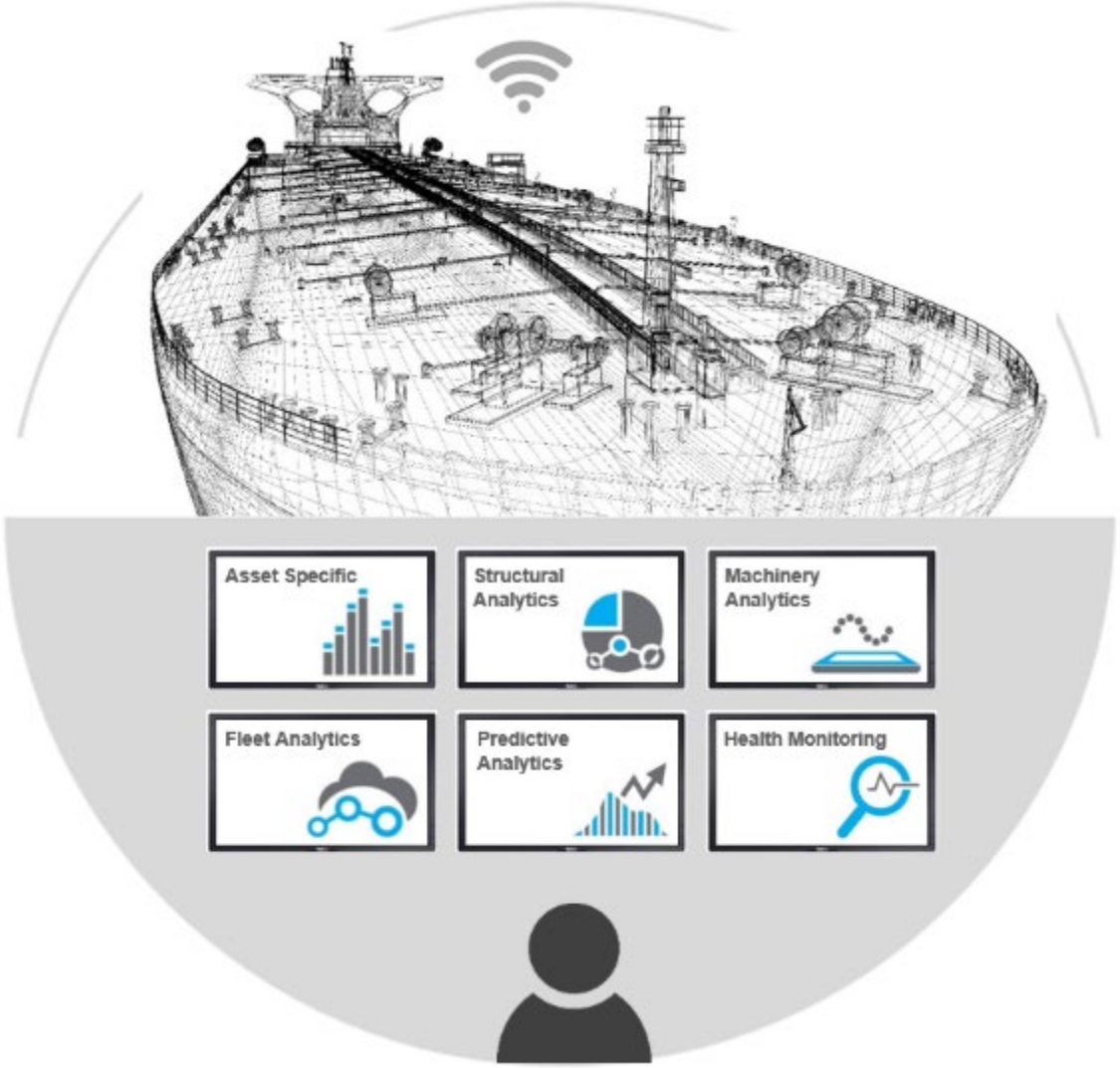
ABS Machinery Analytics



Condition-Based

Systems installed and services deployed:

- to continuously collect, transmit, manage, analyze, and report data
- for enhanced health and condition awareness, operational optimization, and decision-making support



CBP Drivers & Goals

- **Operator Value and ABS Value: Reduce Survey prep and support as well as survey effort on board when risk profile is low and address risk when a profile is medium to high…**
- Operator's Perspective:
  - **Operator's Pain Points for Class Survey After Construction:** OPEX value from CBP service tiers towards failure reduction, maintenance and spares optimization, availability planning and readiness assurance.
- Direct Cost-Benefit for CBP:
  - **Reduce survey footprint** and effort for on-board survey task scopes, including crew prep time and support via any and all data-driven means.
  - **Support an extended period between major availability events** using services from CBP to justify this via low-risk profile. Work in progress with Flags.

The ABS Condition-Based Program

RAW DATA

- Maintenance records, sensor readings, and performance metrics

DATA DRIVEN INSIGHTS

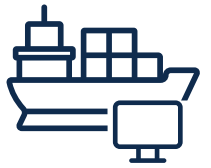
Advanced analytics on asset health, reliability, and predict potential failures

DIGITALLY CONNECTED

Maintenance teams and ABS are connected

MAINTENANCE OPTIMIZATION

Proactive Maintenance & Spares Optimization



Drydock Maintenance Planning

CLASS AND REGULATORY VERIFICATION

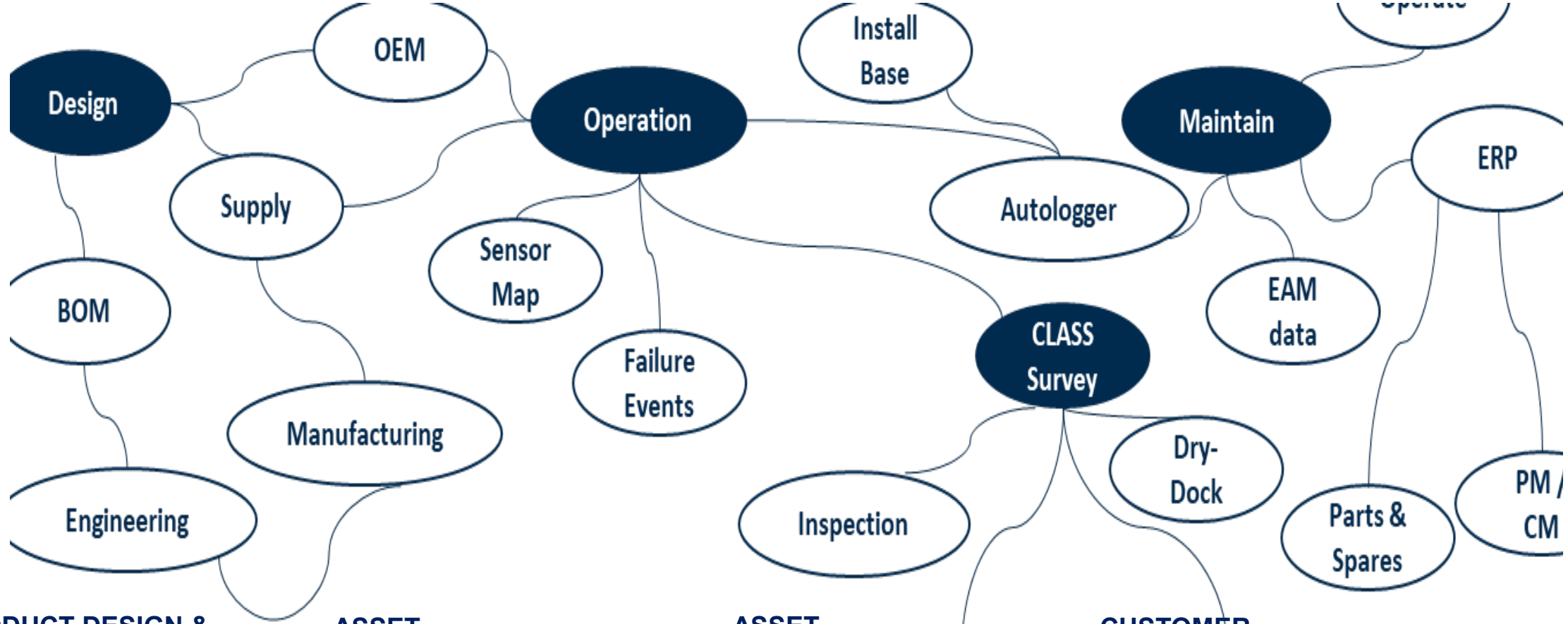
Remote digital verification via ABS Operations Support Center

Streamlined Survey Planning Document with reduced onboard verification time

ABS Objectives

1. ***Leverage insights for Class credit***
2. ***Minimize and optimize onboard Survey scope***
3. ***Enhance the customer experience & ease of Class***

Data OR *'data hairball'*?



Data…what?

Operational Data
- Sensor Data
- Tag Mapping
- Placement & Measurement

In-Situation Tests
- Oil Tests
- Vibration Tests

Events Data
- Failure Events
- Case Findings
- Warranty Logs
- Equipment Breakdown Structure

Parts Consumption
- Planned vs. Unplanned
- Cost of Events

Additional Data
- Demographics
- Ocean Conditions
- KPIs

Inspection / Survey Data
- Gaugings
- Corrosion
- Design & Mods

DATA + DOMAIN + DATA SCIENCE

AI-Based Transformation

Role played by AI today:

- Machinery & structure systems
- Risk assessment
- Inspection & surveys

Where can Industry-Class Collaboration help further?

- Ensuring compliance
- Usage guidance
- Removing adoption challenges

Shipping Trends

- Autonomous (but not unmanned!)
- AI presence in operations, route planning
- Cybersecurity and readiness

AI Adoption and Responsibility

DATA AND DATA QUALITY

- Data isn't created equal
- Data Rationalization

ROLE OF HUMAN SME

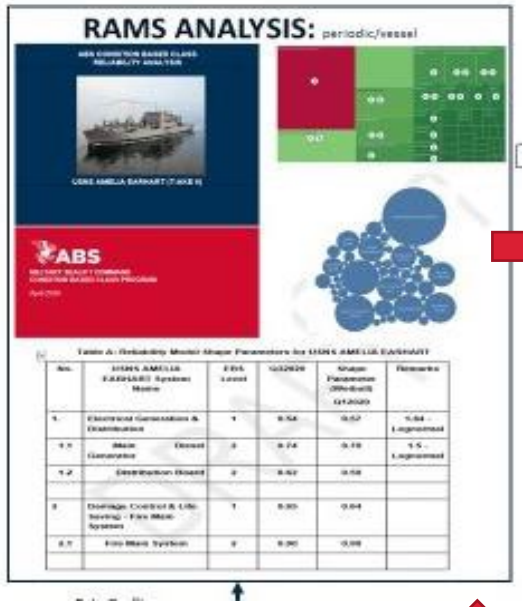
- Predictive AI vs Human SME
- Decision Support vs. Decision System
- Actions vs. Assessment

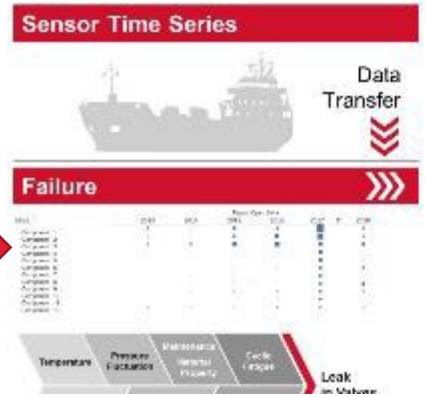
POST 'AI'

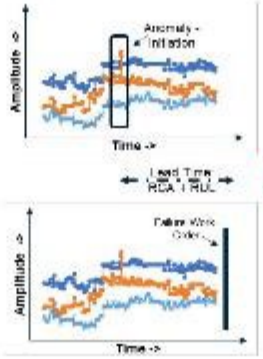
- Done and Done
- Continuous Improvement

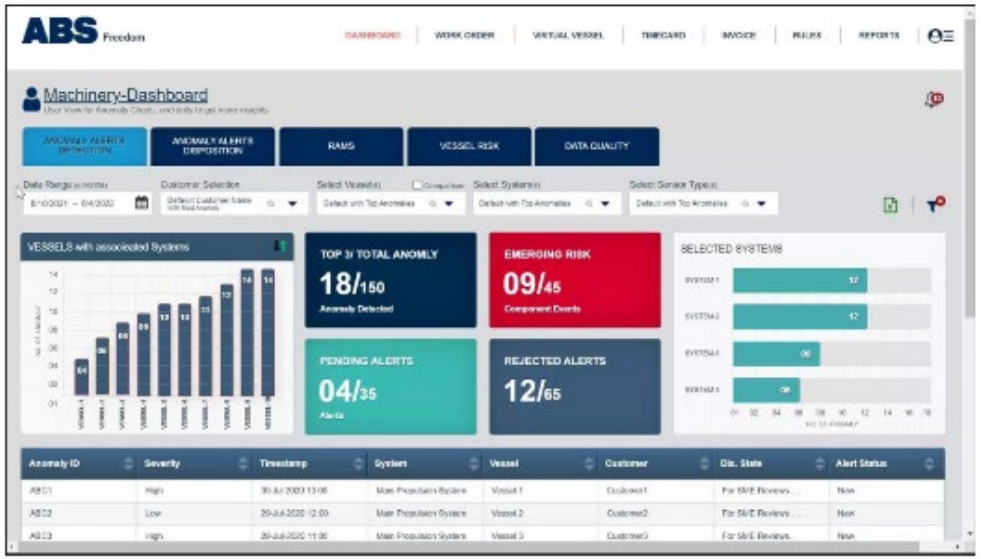
What Enables This CBP Approach - Machinery

- Traditional "**PMP on Steroids**": PMP data automated/trended (Tier 1) + CMMS/RAMS analysis (Tier 2) + Targeted Anomaly Detection on Critical Equipment/Systems and "bad actors" (Tier 3)



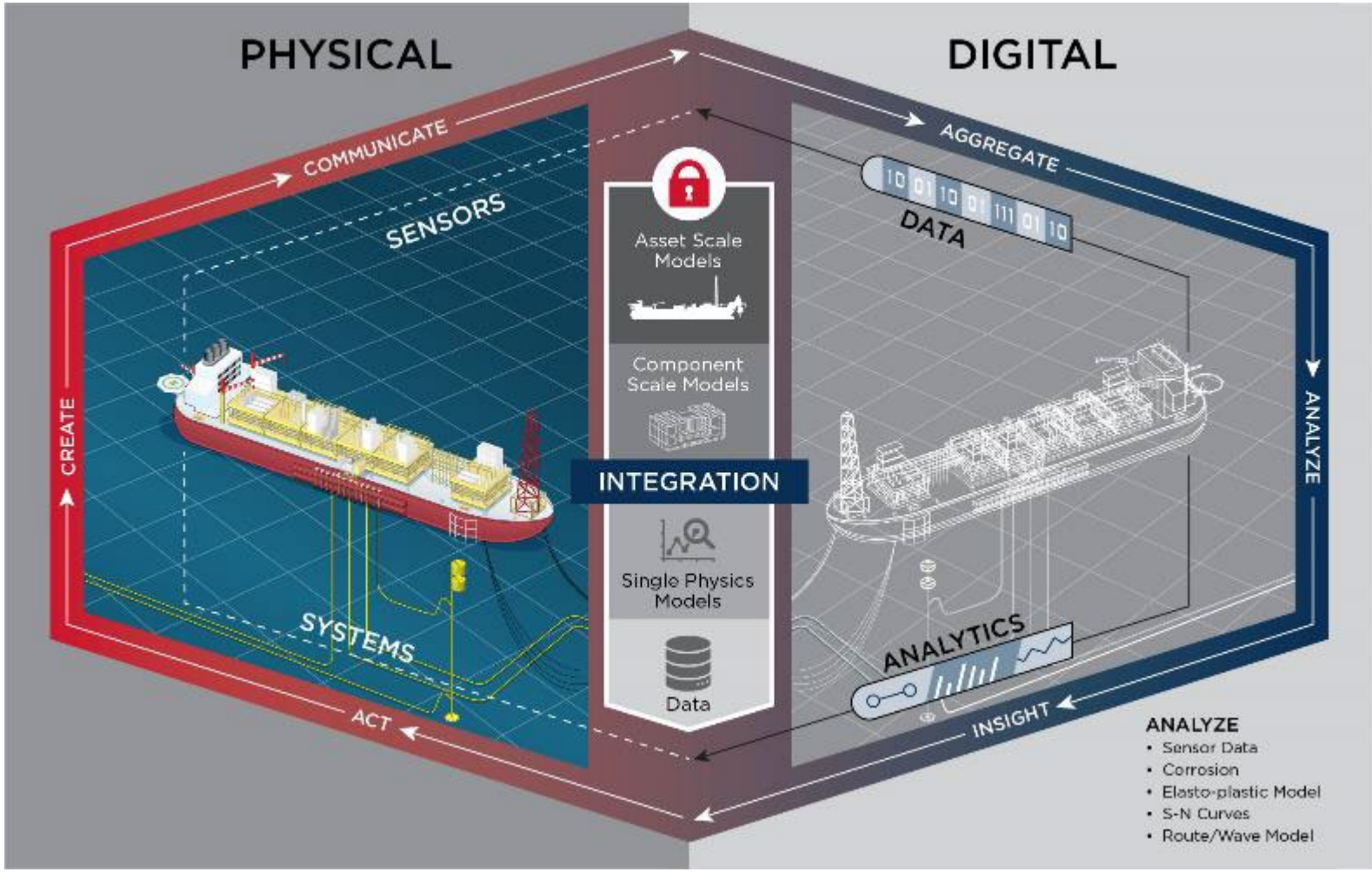






Digital Twin Definition

- A virtual representation of a physical system (and its associated environment and processes) that is updated through the exchange of information between the physical system and virtual representation.



Reliability & Availability Risk Analysis

Operational RAM enhancement

Quantify operational RAM risks

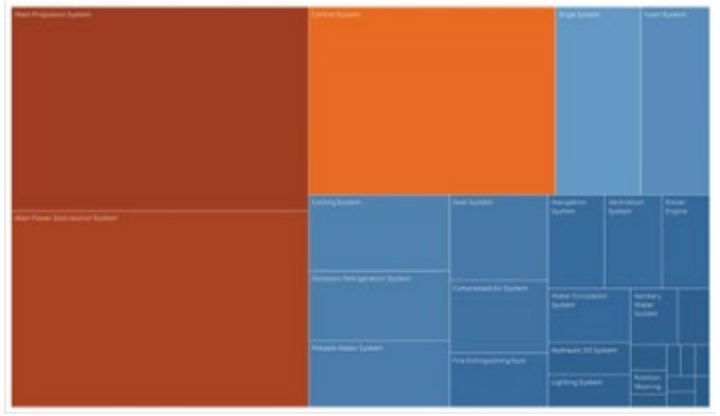
- Benchmark current reliability of major sub-systems.
- Identify emergent reliability risks
- Provide reliability trends over time
- Quantify the relative risk in reliability amongst multiple maintenance facilities

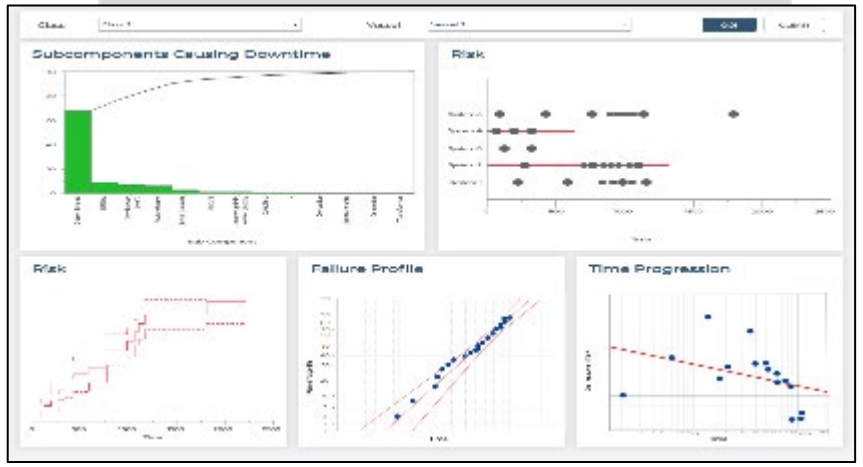
Quantify Asset to component level risks

- Statistical & Risk models to benchmark baseline reliability risks
- Fleet wide risk assessment
- System to Component level models

People or Process or Product ?

- Identify main factors causing RAM risk
- Data improvement





Sensor Based Anomaly Detection

- Detecting anomalous signatures for proactive maintenance planning

Performance Analysis

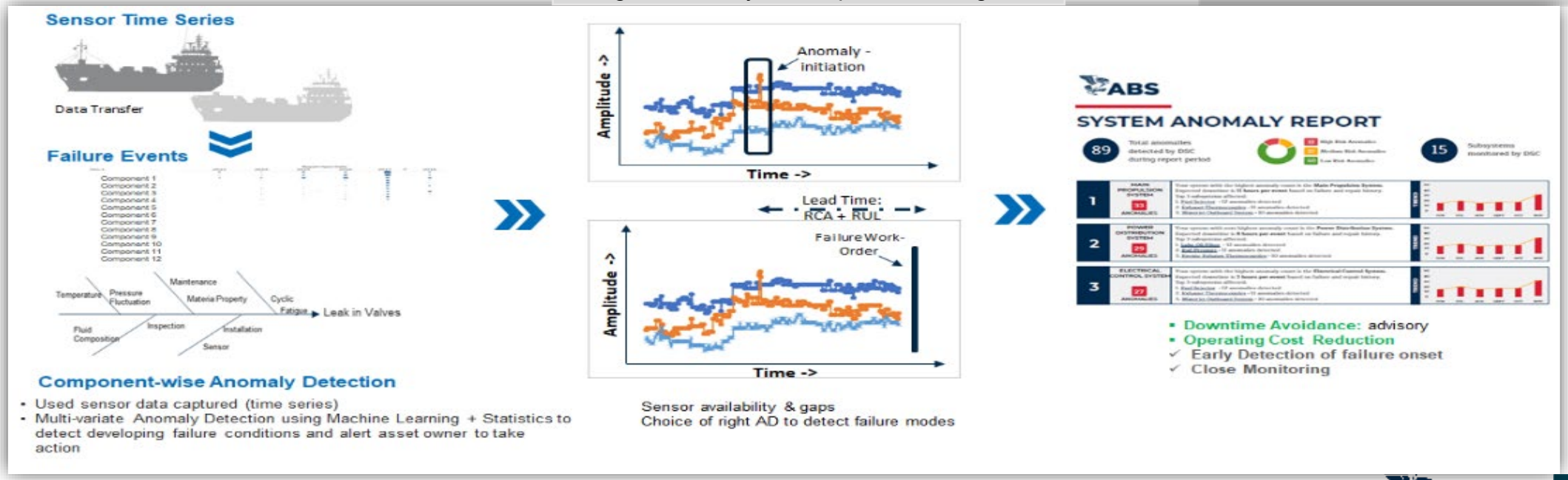
- Detailed analysis of an asset's or fleet of assets machinery performance

Collect additional data

- Fusion of sensor, survey and customer data
- Signature analysis and pattern mining

Identify, monitor and predict anomalies

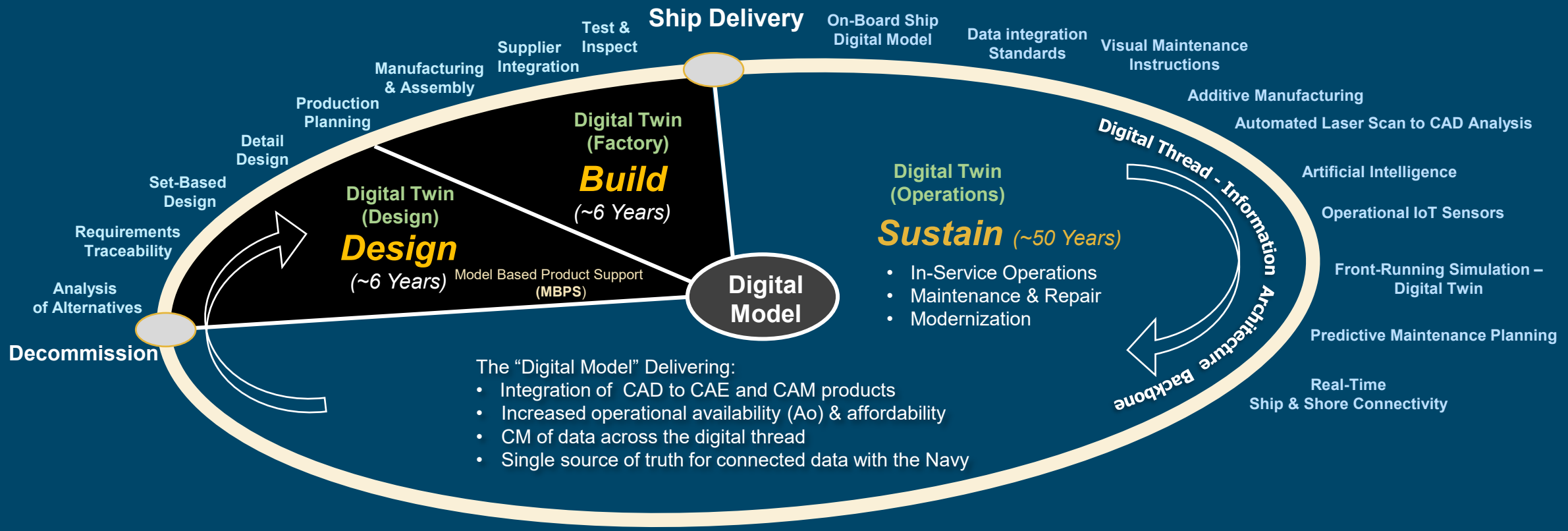
- Reoccurring reports and alerts of identified anomalies



CBP Success Stories

- Detection of incipient hardware issues for maintenance scope planning
  - Detected failed cylinder components causing overheating. The cylinder was replaced due to continuous exposure
- Augmenting onboard crew's efforts: covering equipment not monitored
  - Covered components like splash oil temperatures not actively monitored by onboard crew, complementing the crew's effort
- Quantification of availability impact caused due to specific damage descriptors:
  - Human errors/installation issues identification from fleet wide maintenance history
  - Insights were used for maintenance planning, personal training and enhancement of processes
- Estimation of remaining life in critical equipment
  - Used instrumentation data and manually collected engineering data to identify remaining life for sea water pumps. Insight was used to inform inspection scheduling
- Developed fleet benchmarking for systemic and specific failures & impact to reliability
  - Reliability analysis and reporting of changes across sister vessel fleet covered. Insight used for tracking fleet reliability health, identify systemic damage descriptors for process-maintenance process changes

The Shipbuilding Digital Thread
will require
Advanced Capabilities



Advancing Digital Data Management through the Ship's Lifecycle

Building “Failure Data & Prediction Models” for Ship Construction & Sustainment Support

ISSUE to ADDRESS: Sustainment costs for ships continue to be a large and difficult to manage cost for the Navy and other services. Considerable effort is being spent on sensing and measurement of parameters that may help identify and predict failures. However, there remain substantial opportunities to extract much more value from the amount of data already being collected.

Historical challenges that the Navy and other government fleet owner/operators have had in tackling ship sustainment costs.

Sustainment Cost	Ticonderoga Class cruiser (CG-47)	Nimitz Class aircraft carrier (CVN-68)	Arleigh Burke Class destroyer (DDG-51)	Freedom Class littoral combat ship (LCS-1)	Independence Class littoral combat ship (LCS-2)	America Class amphibious assault ship (LHD-6)	Wasp Class amphibious assault ship (LHD-1)	San Antonio Class amphibious assault ship (LPD-17)	Whidbey Island Class dock landing ship (LSD-41)	Harpers Ferry Class dock landing ship (LSD-49)
Service life longer than expected	●	●							●	●
Unexpected replacement of parts and repairs		●	●	●	●		●	●		●
Access to technical data		●								
Delays in depot maintenance	●	●	●	●	●	●	●	●	●	●
Delays in intermediate maintenance	●		●		●		●			
Shortage of trained maintenance personnel	●		●	●	●	●	●	●	●	●
Unscheduled maintenance	●	●	●	●	●	●	●	●		
Diminishing manufacturing resources	●	●	●		●		●			
Parts obsolescence	●	●	●	●	●		●	●		●
Parts shortage and delays	●	●	●	●	●		●	●	●	●

● Applicable maintenance issues

Source: GAO Analysis of Navy Information | GAO-23-106673

Note: Diminishing manufacturing sources refers to loss, or impending loss, of manufactures or suppliers of items, raw materials, or software.

This project addresses ISSUES common to the Entire Navy and all US Shipbuilders

Building “Failure Data & Prediction Models” for Ship Construction & Sustainment Support

OBJECTIVES:

- **Provide a failure data readiness/quality assessment and develop a roadmap for government fleet owner/operators and shipyards to:**

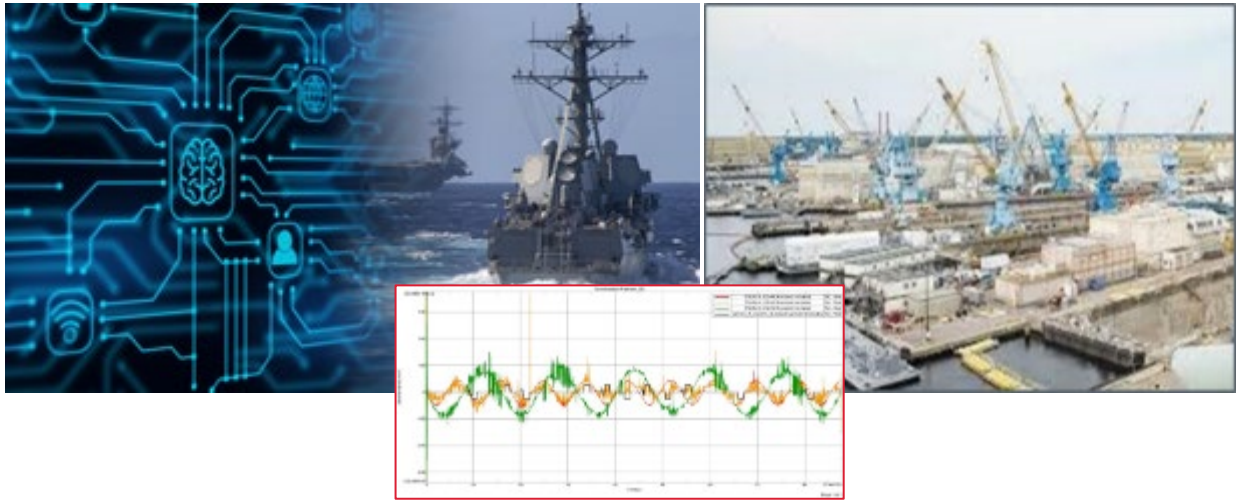
  (1) Optimization yard availabilities and

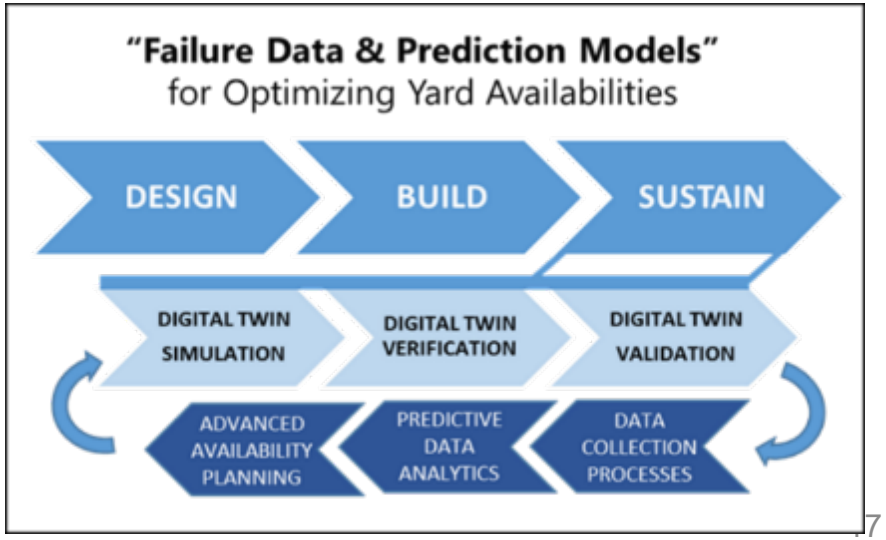
  (2) Provide feedback to follow-on vessels using advanced data analytics of available ship condition.

- **Lay the foundation for increased use of advanced data analytics that reduce:**

  (1) The cost and improve the predictability of scheduling for yard availability periods for ships and

  (2) The total cost of ownership of ships produced and sustained by yards, especially due to unrecognized vulnerabilities and material conditions that lead to failures.





HII ABS

Building “Failure Data & Prediction Models” for Ship Construction & Sustainment Support

Significant Benefits:
Reduce the cost and improve the predictability of scheduling for yard availability periods for ships, and eliminate recurring failures within a vessel class by addressing critical system issues during new construction of subsequent ships, providing major savings for government owner/operators and shipyards while also improving mission availability.

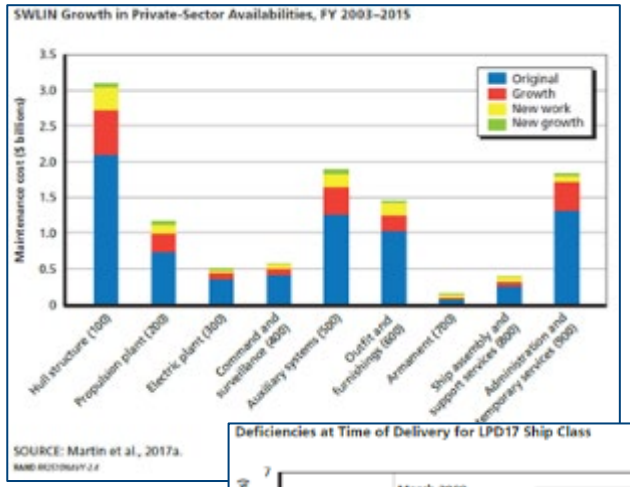
Benefit 1: Reduced Costs for Government Owner/Operators Tied to Unrecognized System/Equipment Conditions.

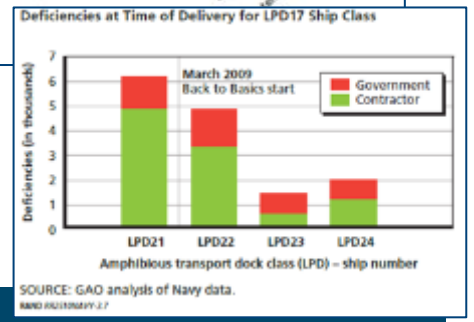
- Reduce Growth Work During Availabilities, and/or
- Reduce Subsequent Damage/Defect-initiated Availabilities.

Benefit 2: Value of Operational Days That Would Have Been Lost to Extended Availabilities Because of Unrecognized Conditions.

Benefit 3: Value to Shipyards from Improved Predictability of Yard Availabilities.

Benefit 4: Value to the Government Owner/Operators and/or Shipyards Generated by Mitigating Equipment/System Issues in Subsequent Ship Construction.





ROI:
Foundational steps for unlocking value of data analytics to improve ship construction and sustainment (>100x the cost of this project)

Project – Ship Type Data Selected for Evaluation

We selected the LPD 17 ship class because:

- We have access to all operational LPD 17 class ships through OARS, anything operational last 9 years
- We have access to any system test failures from factory-acceptance through delivery, since we have the construction contract
- Because we have the maintenance contract, we also have knowledge and data on repairs while ships in operation come in for MRO
- Since the ship class has a history and continues to be built, we would theoretically have access to failure data at all ages of ship hulls

Next Steps:

Phase 1 will focus on the failure and condition data needed to support the use of advanced data analytics, including the types of data needed, current and future availability of such data, owners of the data and how to access the data, and how to assess/improve the quality of the data.

Phase 1: D1 - Report on Failure Data Sources, Availability, Quality, & Potential Uses

Phase 1: D2 - Recommendations on Necessary Data Improvements

Phase 1: D3 – Representative Data Sets for Data Analytics Demonstration Cases

Summary:

We will enable the ability to unlock the power of failure/condition data sets through advanced analytics, including tools such as Artificial Intelligence (AI) and Machine Learning (ML) as well as more traditional reliability engineering techniques, by

(1) alignment of the many stakeholders engaged in the availability planning / execution process,

(2) Providing the critical technical insights to identify and address early failures for planned and scheduled corrective action, and

(3) providing a feedback loop to eliminate vulnerabilities during construction of subsequent ships in a vessel class.

We will provide a failure data readiness/quality assessment tool to improve ship availability work identification process and accurately schedule to reduce unscheduled work and time-at-dock.

Key Lessons Learned

AI-based CBM is for YOUR assistance only!

What will I do and get?
Why should I trust?

DATA ACQUISITION

- Resolution
- Connectivity

DATA QUALITY

- Fleet Variation
- Instrumentation
- Context-based

CHOICE OF AI METHOD

- Data Types
- Bias VS Variance
- Complexity
- Maintainability
- Explainability – trust!

CBM PLATFORM CHOICE

- Orchestration
- Consumption
- HMI and UX for PHM

CBM ADOPTION

- User Training
- Shelf-life of an analytic
- Drive Credibility
- Fatigue
- Feedback

Thank You for your participation.

Discussion…