Integrated Digital Shipbuilding

"Concept of Operations" for a "Model Based Enterprise"

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Digital Thread

“Information Connected Digital Enterprise”

Scoping & Design
Concept Design
Arrangement Design
Detail Design
Production Planning
Fabrication, Assembly
Manufacturing Engineering
Supplier Integration
Fabrication, Assembly
Test & Inspection

Requirements
CAE Analysis
3D Model
PMI
EBOM
PBOM
Visual Work Instructions
Work Packages
Requirements Validation
Close-Out Work Certification
Technical Manuals/Documents

Disposal Work Package
Execution Work Documents
Availability Planning

“NNS’s Shipbuilding Digital Thread”

Decommission
Maintenance, Modernization & Repair
In-service Operations (Ship Force)
Ship Delivery

IN-SERVICE (LIFECYCLE) AUTHORITY
TECHNICAL AUTHORITY
BUILD AUTHORITY

People, Processes, & Information
Connecting

Digital Thread

“Information Connected Digital Enterprise”
**Model Base Enterprise (MBE)**

“Maturity Capability Levels”

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Primary Deliverables</th>
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<tbody>
<tr>
<td><strong>Level 6</strong></td>
<td>Model Based Enterprise – Integrated Manufacturing – Integrated Extended Enterprise</td>
<td>Digital Product Definition Package and TDP via the web</td>
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<tr>
<td><strong>Level 5</strong></td>
<td>Model Based Enterprise – Integrated Manufacturing – Integrated Internal Enterprise</td>
<td>Digital Product Definition Package and Technical Data Product (TDP)</td>
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<tr>
<td><strong>Level 4</strong></td>
<td>Model Based Definition – Integrated Manufacturing – Disconnected Enterprise</td>
<td>3D Annotated Model and Light Weight viewable via PLM</td>
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<tr>
<td><strong>Level 3</strong></td>
<td>Model Based Definition – Native Model CAM – Disconnected Enterprise</td>
<td>3D Annotated Model and Light Weight viewable</td>
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<td><strong>Level 2</strong></td>
<td>Model Centric – Native Model CAM – Disconnected Enterprise</td>
<td>2D Drawing and Native CAD Model</td>
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<tr>
<td><strong>Level 1</strong></td>
<td>Model Centric – Neutral Model CAM – Disconnected Enterprise</td>
<td>2D Drawing and Neutral CAD Model</td>
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<td><strong>Level 0</strong></td>
<td>Drawing Centric – Disconnected Manufacturing – Disconnected Enterprise</td>
<td>2D Drawing</td>
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Business Process Productivity and Efficiency Improve when Moving Up the Capability Levels.
Technical Authority/ Build Authority/ Lifecycle Authority: Relationships in a Model Based Enterprise (MBE)

“Integrated Digital Shipbuilding”

Planing

Activities 1-10, 20

Technical Authority (TA)

As-Designed (TA)

As-Built (TA+TVD’s)

Activities 21-30

In-Service Authority (LA)

As-Maintained (TA+TVD’s + Maintenance)

In-Service (LA) (TA+TVD’s+Maintance +Upgrades)

Planning

(Maintenance Availability)

Activities 11-20

Build Authority (BA)

Shop Manufacturing (BA+ MFG)

Ship Assembly & Test (BA+ MFG+ PMI)

In-Service (LCM) Linked Model (BA)

Shop Manufacturing (BA+ MFG)

Ship Assembly & Test (BA+ MFG+ PMI)

External Customers
TA - Engineering & Design Processes
(Technical Authority - TA)
“Integrated Digital Shipbuilding”

1. Initialize Ship Environment
   - Establish IDE: Customer, Vendor Interface
   - Set-Up Project environment (IT; HW/SW database, etc)
   - Set-up data and Security Models
   - Set-up parts Catalogs
   - Define configuration (effectivity)
   - Track/link ORD requirements
   - Define contract type; TA, BA or sequential
   - Identify tool interfaces
   - Establish collaboration IDE

2. Develop Concept Design
   - Enable data workflow, standardized reporting
   - Set-up parts Catalogs
   - Define configuration (effectivity)
   - Establish Hull form
   - Conduct analysis (systems)
   - Develop modeling schedule
   - Set-up ship reference grid, decks & bulkheads, molded conventions, etc.
   - Place structure, major eqpt, GFI distributed systems, passage volumes
   - External customer view access

3. Develop Arrangement Design
   - Finalize hull form
   - Conduct 3D Arr. level part modeling, access and removal paths, space reservations, tanks, etc.
   - Conduct initial base level planning (BA)
   - Define view partitions/groups
   - Create workflow for process review
   - Conduct analysis, FEA, Wt & CG...
   - Extract material forecast (BA)

4. Develop Detail Design
   - Finalize design 3D piece parts
   - Apply welding joints
   - Finalize base level planning (BA)
   - Extract list-of-material (long-lead) (BA)
   - Conduct design reviews
   - Gain Customer approval
   - Lock design models
   - Create standard product reports

5. Load (TA) PMI for Detail Design
   - Configure TA PMI Libraries & Catalogs
   - Create Weld symbols catalog, inspection requirements
   - Create dimensions format
   - Define notes catalog

6. Develop ShipBOM / Material List
   - Auto report SBOM / Material List
   - Planning create Base group structure assign events & milestones (BA)

7. Develop (TA) Part and Assembly PMI Views
   - Start Compartment Level Management
   - Author PMI GD&T objects base on (TA) rules
   - Author text instructions
   - Reuse standard text fragments from library
   - Coatings & coverings
   - Add symbols, collection data fields
   - Define part view groupings/partitions

8. Add Reference Documents to Data Base
   - Add specification documents & procedures as attachments to the Technical Authority
   - Add reference documents – Mil-Specs, inspection criteria, etc.
   - Add deviation and waver documents

9. Validate (TA) PMI
   - Perform Validation Activates for TA data.
   - Perform PMI variation analysis
   - Save PMI and lite weight Context
   - Object removal paths, pull space, human ergonomics
   - External customer share/access

10. Release (TA) Models to (BA) for Mfg & Assy
    - Complete Check lists and Run reports; Wt & CG, holdups, etc.
    - Configure(BA)partition/views build planning
    - SBOM released
    - Lock TA files and prepare for (BA) use
    - Technical data is exported and delivered to (BA) customer
    - Release TA products & deliverables
BA - Engineering & Design Processes
(Build Authority - BA)
“Integrated Digital Shipbuilding”

Decision Authority:
Technical Authority – (TA)
Build Authority – (BA)
In-Service Authority – (LA)

- Denotes Model Based Enterprise (MBE) capabilities

**11 Configure (BA) for Mfg & Assy**
- BA System set-up, user roles-access
- Receipt and validation of customer & TA outputs
- BA objects are defined, Data & Security model updated

**12 Develop (BA) Plan**
- BA plan & schedule development; (high, intermediate, and detail levels)
- 3D Geometry Mfg/Assy; CAM model development, files linked/associated to TA for change notification workflow
- Develop temporary support, jigs & fixtures, lifting pads, etc.
- Generate appropriate (BA) PMI

**13 BOM Management**
- Model Base Work Instructions Automation based on model features and PMI.
- Build BOMs according to functions
- Modify product structure according to manufacturing needs (shop movement)
- Add manufacturing specific parts (consumables, interim parts, etc.)
- Define configuration (effectivity)
- Enable Form, fit, function change notification

**14 Define/Create Work Packages**
- CNC data based on and checked to 3D model, update notification enabled.
- Perform business management activities; Charging, work centers, network association.
- Author processes and sub-processes
- Author operation steps
- Assign consumed parts to operations
- Add resources (tools & fixtures)
- Define sequence of events
- Test & Inspection requirements
- Define CAM requirements; NC data, pipe bending, etc.

**15 Create Visual (2D & 3D) Work Instructions (VWI)**
- Attach 2D images, insert text instructions, add symbols
- Create (optional) animations & simulation for documentation when of complicated assemblies
- Create Product Views (3D snap shots, add mark-up, show PMI, set view points, color)
- Embedded 3D Visualization

**16 Assembly/Release Work Packages**
- Smart model recognition routines provide automation of work instructions.
- Associate BOM and Visual work instructions to work packages
- Publish BA Work Instructions
- Develop planning & execution products & deliverables (LA)

**17 Manufacture Products**
- Perform manufacturing operations, Trades execute work
- Add documents / attachments to operations, such as operation sheets
- Add reference documents – safety plans

**18 Assemble Products**
- Perform assembly operations, Trades execute work
- Add documents / attachments to operations, such as operation sheets
- Add reference documents – safety plans

**19 Perform Test Activities**
- 3D Models, products and process definition accessed from workstation computer.
- Visual Test Instructions, Model based Test & Inspection
- Trades execute work

**20 Close-Out / Work Certification**
- 3D Models, products definition available
- Close-out transactional work activities
- E-signatures added to documents
- (TA) develops and delivers technical manuals for ship In-Service Maintenance
LA - Engineering & Design Processes
(In-Service Authority - LA)
“Integrated Digital Shipbuilding”

Notes: Type Commander (TYCOM): NAVY Ship Owner Issues AWP.
Planned Incremental Availability (PIA) 20 → 25

21 Utilize 3D models (TA+TVD’s)
- 3D Models, products definition available to Navy Stakeholders.

22 Perform In-Service Modernization/ Maintenance “Logistics”
- Laser scanning and Augmented Reality practices support shipboard configuration to product model configuration verification.
- Laser scanning, digital photogrammetry / Ship check data incorporated into 3D model
- Reconcile 3D model complete (Proofing)

23 Perform 3D Virtual Ship Checks
- Finalize 3D model geometry to reflect Ship at-sea configuration
- Laser scanning, digital photogrammetry / Ship check data incorporated into 3D model
- Reconcile 3D model complete (Proofing)

24 Receive Availability Work Package (AWP)
- Finalize decisions on work content applicability and perform planning activities
- Define required materials, resources and work content time estimates
- Extract Technical Data to create Work Package

25 Update Environment for (LA) Development
- Verify data and security models to support LA view of the data
- Show PMI, set view points, color, etc.
- Parts catalog updated
- External Customer exchange access

26 Perform (BA) Mfg & Assy Activities
- Perform/Execute Authorized Work

27 Perform Availability Planning (LA)
- Update Models
- Perform/Execute Authorized Work

28 Perform Refuel Complex OverHaul (RCOH) or other availability (BA)
- Update Models
- Perform/Execute Authorized Work

29 Perform Availability Planning (LA)
- 3D Models, products definition available on-board In-Service ship.

30 Decommission Ship Activities (BA)
- Perform/Execute Authorized Work

Concept Studies
- Define configuration (effectivity)
- Integrate TVD changes with TA as-designed model
- Receipt of Customer & BA outputs
- Executing (Build) organization identified

Ship Maintenance Availability
- Execute planning yard, fleet activity work and Operational support
- Finalize 3D model geometry to reflect Ship at-sea configuration
- Laser scanning, digital photogrammetry / Ship check data incorporated into 3D model
- Reconcile 3D model complete (Proofing)

Ship to Sea
- Perform/Execute Authorized Work

Develop (BA) Plan 3D Geometry & PMI
- Close-Out / Work Certification
- Develop As-Built 3D model (TA+TVD’s)
- Work Disclosure to (BA) - Navy
- Close-Out / Work Certification
- Develop (BA) Plan 3D Geometry & PMI
- Work Disclosure to (BA) - Navy
- Close-Out / Work Certification
- Develop As-Built 3D model (TA+TVD’s)
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- Develop (BA) Plan 3D Geometry & PMI
- Close-Out / Work Certification
Integrated Digital Shipbuilding – Key Tenets

- “Learn by doing” iterative process development
- Innovation and discovery are necessary for defining uncertain processes
- Create an agile development environment for process evaluation
- Grassroots idea collection
- End-to-End data Configuration Management
- COT’s software to greatest extent possible
- Need to support a Collaborative environment
- Agility to upgrade technology faster
- All product data managed by TeamCenter
- Drawingless Model Based Environment
- Convergence on common business processes
- Additive data content through product phases
  - Create once use many times
- Change of data ownership across phases
- Communication and feedback of product information
- Data synchronization and flexibility to handle different use cases
- Continuous material management
- Model Based (PLM) Piece part management, not drawing base hierarchy
- Planning flexibility for continuous improvement
- Integration between IT Systems, no data copy

Business Process changes must be evaluated for end-to-end value stream impact
MBE is a journey – build as you go
Teamcenter- Integrated Configuration Management

Integrated Configuration Management and Change Control

Teamcenter Maintains Integrated Asset Configuration Throughout The Lifecycle of an Asset

- As Designed
- As Built
- As Contracted
- As Supplied
- As Installed
- As Maintained

LIFE CYCLE INTEGRATED DATA ENVIRONMENT
Configuration-Driven Service Management

- Configuration Management
  - “As-Built” / “As Delivered” moves to “As-Maintained”
  - Physical product structure updated as it evolves over time, including life characteristics values, failures, replacements.
  - Captures the complete history of the structure as it evolves

**As-Built**
- Definition of the physical product structure captured in production
- Captures deviations from the planned design
- Captures serial numbers, lot numbers, installation dates etc

**As-Maintained**
- Definition of the physical product structure captured when ship is delivered and maintained through asset life
- Captures deviations from the planned design
- Captures material history of each asset

LIFE CYCLE INTEGRATED DATA ENVIRONMENT
Enhance and optimize the service lifecycle with a platform that brings together service knowledge, people, applications and activities.
Technical Data and Maintenance Attributes

Management of Configuration Relationships

Relating technical documentation and maintenance attributes to product structure is one of the most important aspects of configuration control. It is essential to have visibility of product to document / data / attribute relationships in order to successfully execute impact assessments and ensure the accountability of all maintenance and modernization requirements.

IP Management, including content and document management

Published Technical Docs
- Maintenance Standards
- CAD Assembly
- Engineering Drawings
- Standardized Test Proc.
- Master Spec Catalog
- Annotations
- Publishing results

Maintenance Details
- Maintenance Category
- TDP
- Assessment / Inspections
- Other Attributes
PLM: Naval Ship Maintenance Cycle

PLM manages the SLM data and provides the capability to execute the Navy’s Maintenance processes

Develop the Work Package
The Maintenance Planning Activity blends the Class Maintenance Plan, Corrective Maintenance and Modernization into an integrated Availability Work Package, funded by the respective customers.

Plan The Availability
The Availability Planning Activity (usually the NSY) develops the Technical Work Documents, sources and acquires the material and develops the integrated execution schedule while performing risk reduction analysis and sourcing the workforce.

Execute the Availability
The LMA (usually a NSY) performs the work, maintaining quality, controlling cost and managing resources to achieve the integrated schedule.

Test and Certify the Work
During execution, the completed work is inspected, tested and certified within the same integrated schedule.

Deliver to the Fleet
A fully certified vessel is delivered by the LMA to the Fleet, essentially ready for unrestricted operations.

Commence Planning 4-20 months Commence Availability Dock 4-24 months Undock 1-6 months Complete Availability

Analyze and Reduce Risk Maintain Schedule Respond to Work Discovery and New Work Respond to Test Failures

Span times are representative for CNO Availabilities

LIFE CYCLE INTEGRATED DATA ENVIRONMENT