The Digital Thread Beyond (Product Engineering) and Back

New Program Requirements are dictating the creation and management of the "Digital Twin"

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iBASEt: Your Partner for Success

Global Product Data Interoperability Summit | 2018

• End-to-End digital integration of engineering and change control across the value chain
• Well defined Out-of-the-Box best-in-class processes, get up and running quickly
• Integrated Quality Management across Manufacturing Value Chain

• Only vendor solely focused on solving complex manufacturing and sustainment issues
• Professional Services team: 20+ years of Complex Mfg & MRO Operations experience
• Partner Network of global system integrators to help accelerate roll outs

• 60,000 Solumina users
• 80% of Leading Complex Manufactures have chosen iBASEt
• 30 years of organic growth through Customer Success – not – M&A
The Solumina software solution suite is designed to make highly complex OEM and maintenance enterprises simple, combining, in one suite a MES, QMS, SQM and MRO

- Easily integrated to the CAD, PLM, and with the ERP
- Preconfigured and easy to implement (“Out Of The Box”)
- Offering easy-to-use graphical interface
- Built according to the “lean” philosophy

+ of 150 factories and +60,000 users in the world work with Solumina
Our Highly Complex Manufacturing Customers

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Aircraft Components

- Lockheed Martin
- Parker
- Rolls-Royce
- Pratt & Whitney
- NORDAM
- UTC Aerospace Systems
- Jabil
- GE Honda Aero Engines

Industrial & Fabricated Parts

- Solar Turbines
- Harcostarco
- Jabil

Commercial & Military MRO

- L3 Communications
- U.S. Air Force

Airframe Assembly

- Sikorsky
- Gulfstream
- Cirrus Aircraft

Military & Classified Weapons

- Orbital ATK
- General Dynamics
- National Security Campus
- Nammo
- Sandia National Laboratories
- Los Alamos National Laboratory

Space Products

- Orbital ATK
- NASA
- Airbus Defence & Space
- Boeing
- Northrop Grumman
- Virginia
- Orbit

Medical Device & Equipment

- Earlens

Naval Components

- Textron Systems
- BWXT

4
3 Percent

That’s how much of a Complex Discrete Manufacturer’s revenue doesn’t make it to their bottom line.
Why are Executives Rarely seen getting excited about wasting 3 percent of revenues?

- Those dollars are rarely reported as waste.
- The more profitable a manufacturer is, the less it realizes that money is being wasted.
- Entire management practices and methods characterize these as Costs (The Cost of Doing Business)
- What we often hear early in the discovery:
  - “This is what it costs to Design, Plan and Execute at our company”
  - “We are world-class leaders in quality and efficiency for our industry”
The Digital Thread - Definition

In Brief, the Digital Thread represents the sum of all model data, product structure data, metadata, effectivity data, process definition data including supporting equipment and tools that are **DIGITALLY LINKED** together to form a single, contiguous definition of all value-added decision made during the definition of a product, its configuration, manufacturing and repair processes, logistics (vendors and subs) and operational support (PBL).
WHAT IS THE KEY TO THIS **DIGITAL THREAD** LINK?

**THE CAD ID!**
de7a8e65-ff17-447a-8b33-7a27e4f37bac

We Fetch and store it for every Item listed in a Bill of Material.

The CAD ID is the backbone of the digital Thread!
### WHAT DOES A DIGITAL THREAD COMPLIANT BOM LOOK LIKE?

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>REV</th>
<th>BOM LINE</th>
<th>CAD ID</th>
</tr>
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<tbody>
<tr>
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<td>F</td>
<td>001</td>
<td>84365289-16c9-4621-bb20-346ff81bd82</td>
</tr>
</tbody>
</table>

### WHAT DOES A NON DIGITAL THREAD COMPLIANT BOM LOOK LIKE?

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>REV</th>
<th>QTY</th>
<th>BOM LINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>4545-24313-1</td>
<td>F</td>
<td>2</td>
<td>001</td>
</tr>
</tbody>
</table>
The Digital Thread–Data Model

• What Data Categories Make up the Digital Thread?
  • Part Numbers
  • 3D Models
    • Surfaces, dimensions, tolerances, datums,
    • Metallurgy, hardness,
    • Metadata (DFMEA, key characteristics, control limits)
  • Item Master Data
    • Authorize Sources
    • Inventory Locations, levels, replenishment methods
  • Bills of Materials, effectivities, options and features
  • Bills of Processes (Fabrication, Assembly, Integration, Test)
  • Service Intervals
  • Much, much, more…
A PLE like Solumina enables:
DIGITAL THREAD COMPLIANT Process Definition, Manufacturing and MRO Execution, Defect Management, Engineering change and Supply Chain Management throughout the life of the Program and Units.

**WHAT is a PLE?**

A PLE like Solumina enables:
DIGITAL THREAD COMPLIANT Process Definition, Manufacturing and MRO Execution, Defect Management, Engineering change and Supply Chain Management throughout the life of the Program and Units.

**SQA**
- Quality Requirements Planning
  - Product Characteristics and Requirements
- Supplier Quality Planning
  - Product Inspection Definition
- Supplier Quality Correction
  - Supplier Discrepancies and Corrective Action

**MES/QMS**
- Manufacturing Reqt’s Planning
  - Product Characteristics and Requirements
- Process Planning
  - Manufacturing Process Definition
- Process Quality
  - Discrepancy and Corrective Action

**MRO**
- MRO Requirements Planning
  - MRO Requirements Definition
- Process Planning
  - MRO Routine Work and Process Planning
- Non Routine Disposition
  - Over and Above, MRO quality, and Sub-work

**Audits and Reporting**
Where does Data get Defined?

The Complete Product Lifecycle from PLM to PLE

Throughout the product lifecycle, key Value-Added elements are defined and inserted into the product / process definition.

Anywhere this data is defined too late, there is a cost, a risk and a quality impact.

Anywhere this data is copied, transcribed or re-interpreted, there is an even higher risk and potential quality impact!
Design Value Added Data

- 3D Modeling
- Virtual Assembly
- Process Modeling
- Engineering Bills of Material
- Quality Control Plans

**ORANGE** items are commonly on the Current Digital Thread
Production Value Added Data

• Model / Drawing - Step Views
• Detailed Work Instructions
• Operationalized Part Lists
• Build Control Sequences
• Traceability Data Req’s Per Contract
• Test Steps and Signoffs Per Contract
• Authorized Supplier Lists & KPIs

**ORANGE** items are commonly on the Digital Thread
Why should we change? What’s the risks?

**Value Added Tasks:**

<table>
<thead>
<tr>
<th>Model Design</th>
<th>E-BOM</th>
<th>M-BOM</th>
<th>Process Plan</th>
<th>Work Orders (WIP)</th>
<th>Finished Goods</th>
<th>Customer Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assigning Basic Alts &amp; Subs</td>
<td>Yield Rates</td>
<td>Operations &amp; Steps</td>
<td>Quantities &amp; Dates</td>
<td>Sales Order Complete</td>
<td>Walk-Thru &amp; Acceptance</td>
<td></td>
</tr>
<tr>
<td>Assigning Make-buy</td>
<td>Phantom Flags</td>
<td>MBOM Operationalized</td>
<td>Priorities</td>
<td>UJD Publish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assigning Contract requirements</td>
<td>Location Based Alternates</td>
<td>Work Center Assignments</td>
<td>Team Assignments</td>
<td>Sell-Off</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selecting Vendors</td>
<td>Installation Sequence</td>
<td>Time Standards</td>
<td>Material Issues</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assigning Macro Lead Times</td>
<td>Units of Measure / Conversions</td>
<td>Tool Usage</td>
<td>Tool Issues</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selecting Materials</td>
<td></td>
<td>Process Spec Assignment</td>
<td>Traceability Data Collection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assigning Macro Planned Costs</td>
<td></td>
<td>Serialization Rules</td>
<td>Sign-offs &amp; Inspections</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assigning Work Locations</td>
<td></td>
<td>SPC Rules</td>
<td>Move from WIP to FG</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Potential Non-Value-Added Tasks:**

<table>
<thead>
<tr>
<th>Transcribing BOM Components</th>
<th>Transcribing BOM Components</th>
<th>Step Visuals</th>
<th>Process/Part Alterations</th>
<th>ECO Rework</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assigning TM Effectivity</td>
<td>Assigning TM Effectivity</td>
<td>Upper/Lower Limits</td>
<td>Parts List Creation</td>
<td>As-Built/DD250 Create</td>
</tr>
<tr>
<td>Assigning Reference Designators</td>
<td>Assigning Reference Designators</td>
<td>Component TM Effectivities</td>
<td>Paper Work Package Create</td>
<td>UJD Data Collect</td>
</tr>
<tr>
<td>Assigning Make-buy</td>
<td>Location Based Alternates</td>
<td>Location Based Alternates</td>
<td>manual Signatures</td>
<td>Paper Packets on CD</td>
</tr>
<tr>
<td>Assigning Contract requirements</td>
<td>GD&amp;T data (PMI)</td>
<td>GD&amp;T data (PMI)</td>
<td>Drawing Lookups</td>
<td>Red-Lines Audited</td>
</tr>
<tr>
<td>Selecting Vendors</td>
<td>Yield rates</td>
<td>Yield rates</td>
<td>Process Spec Lookups</td>
<td>Non-Conformances Audited</td>
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<tr>
<td>Assigning Macro Lead Times</td>
<td>Installation Sequence</td>
<td>Installation Sequence</td>
<td>Manual Calculations</td>
<td>UJD Labels Audited</td>
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<tr>
<td>Selecting Materials</td>
<td>Units of Measure / Conversions</td>
<td>Units of Measure / Conversions</td>
<td>Manual Red Tags</td>
<td>DCMA Audits</td>
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<tr>
<td>Assigning Macro Planned Costs</td>
<td></td>
<td></td>
<td>Manual Precedence Control</td>
<td></td>
</tr>
<tr>
<td>Assigning Work Locations</td>
<td></td>
<td></td>
<td>Manual Operation Activation</td>
<td></td>
</tr>
</tbody>
</table>

**Risks:**

- **L - Model Errors**
- **L - Alternates Errors**
- **M - Alternates Errors**
- **L - Structure Errors**
- **M - Effectivities Errors**
- **M - Quantity Errors**
- **L - TME Errors**
- **M - Duplication of IM Data**
- **L - Overly Tight Tolerances**
- **M - Overly Loose Tolerances**
- **H - Raw Materials Errors**
- **L - Work Center Errors**
- **L - Time Standard Errors**
- **L - Work Center Errors**
- **L - Time Standard Errors**
- **M - Tooling Errors**
- **M - Process Errors**
- **M - Signature / Inspection Errors**
- **M - Precedence Errors**
- **H - Access Rights Errors**
- **H - Raw Materials Errors**
- **H - Model Errors**
- **H - Structure Errors**
- **H - TME Errors**
- **H - Raw Materials Errors**
- **H - Model Errors**
- **H - Structure Errors**
- **H - TME Errors**

**What’s the risk?**
Our Customers are getting smart!

What’s Changed in Defense Acquisition Requirements

• Many new Programs now have Contract Elements that refer specifically to the delivery of a Digital or Cyber artifact that COMPLETELY describes the Model-Based as-Designed, the reconciled As-built (with necessary waivers) and the Quality history (including test results) of the asset.

• Gone are the days where delivering functioning hardware was the only trigger for payment.

• These Digital artifacts need to be created and validated in real-time as each vendor produces their sub-assemblies and as each facility performs the final integration.

• Within 5-7 years, we believe that all Major Defense Programs with have Digital-Twin requirements that make-up a important portion of the payment and Acceptance trigger.
Three Areas Affected by the Digital Thread

Remember
The 3% of Revenue
That never makes it to
The bottom line.
The Three Opportunities presented by the Digital Thread

- Each element of the Value Stream where data is either:
  - Re-Invented
  - Re-Interpreted
  - Transcribed
- INTRODUCES AN OPPORTUNITY FOR DEFECT...
- If the defect is caught in -house, the impact is:
  - Dollars
  - Schedule
- If the defect is NOT caught in-house, the ESCAPE affects the program credibility and repeat unit sales
The Three Opportunities presented by the Digital Thread

- The Digital Thread introduces for the first time a framework of Value-Added-Sustainment:
  - Work Gets gone ONCE
  - Quality variances are resolved ONCE
  - Engineering Changes are processed ONCE

- Let's use an Example: **Step by step visuals** for a Major Defense Program:
  - Quantity of Visuals for entire structure = 150,000
  - Avg. Labor Hours per Visual by Mfg. Eng. = 1.5
  - Avg. No. of Process / ECO Changes per Visual* = 6
  - Average Burdened Cost of Mfg Eng ($/hr.) = 67
  - Cost of NOT having Visuals on Digital Thread** = $90,450,000

* For life of Program
** Immediate Cost only, does not include Risk Cost of Quality cost due to increased opportunities for defect.
The Three Opportunities presented by the Digital Thread

• Even if Costs and Quality Rates were NOT an issue,
• A Program cannot afford any variation that will affect the program’s ability to meet program milestone dates.
• Most programs have penalty clauses that can get triggered by:
  • Late milestone deliveries
  • Escape rates / Missing Traceability Data (UNKs)
  • Unit Commissioning dates
• **BOTTOM LINE:** Programs need stability and little to no process variability. Once a good decision has been made (Value-Added Content), it should be preserved.
Classifying your level of Digital Thread Adoption by Program


**D** – 3D Model Drawings, Paperless Instructions, Manually generated Visuals, Separate Data Collection sheets, Separate Inspection Sheets, Receiving Inspection, Electronic QA System, Paper As-Built Docs.


**A** – 3D Model Views, 3D Bills of Resources & Bills of Process, Integrated Execution, Shop Quality, Supplier Source Inspection, As-Built Data and Process Capability Data (Heat Maps) returned to PLM System.
Here’s a Simple Matrix to determine the best path forward!

<table>
<thead>
<tr>
<th>Grade/Action</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>*</th>
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<tbody>
<tr>
<td>F</td>
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<tr>
<td>A</td>
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</tbody>
</table>
The 4 Incremental Steps (Stages) to getting on the Digital Thread

• **Stage 1**
  - Item Master and Default 3D Visuals.
  - Engineering Bills of Materials.

• **Stage 2**
  - Engineering Changes.

• **Stage 3**
  - E-BOM to MBOM Management in Model Based Space.
  - Enhanced Engineering Changes.

• **Stage 4**
  - Process Management leveraging Model-Based Space for Visuals Creation.
Stage 1: Leveraging Item Master and BOM data in PLE

- You already have an item master that includes default model-based visual data that easily can be used for creating new annotations or model Views. The PLE stores those views directly in the PLM.
- Your Default Bill of Materials (E-BOMs or Combo E/M-BOMs) already have most of the needed data for Manufacturing
  - Effectivities
  - Alternates
  - Phantoms
  - Standard positions (LIDs, SINs, Ref Des, Find Numbers)
  - Default BOM Model-Based Visual with Thumbnail.
  - CAD IDs (For Instance-based reconciliation)
- This BOM Data is reconciled to the Process Plans AND Unit Histories by The PLE.
Stage 2: Leverage PLM Engineering Change messages in the PLE

- Engineering Changes are difficult. They reach all over the Planning data and shop floor systems and never end… Mistakes are not only common, they are a virtual certainty.

- ONE Engineering Change can involve hundreds of discrete actions that need to affect some data, skip other similar data and all changes need to be traceable and auditable.

- Use the structured ECO Messages and Bill of Resource updates to allow the PLE to create a SCRIPTED list of changes for Process Plans, Work Orders, Inspection or Sampling Orders and Discrepancies.

- First Article rules will automatically be triggered by the Engineering change actions

- Employees will be individually alerted to any changes since their last completion.
Stage 3: Leverage your PLE Tools to Manage MBOM Creation and Reconciliation

- EBOM to MBOM Transformation is the most costly source of Process Definition mistakes in A&D manufacturing.
- Classical methods for creating and maintaining MBOMs provide little in the way of reconciliation to the PLM Model-Based data.
- EBOMS and MBOMS created from one another in the PLM tool maintain a traceability that is important for making revisions and evolutions less error-prone. The visual Model-based tools also make engineering changes across multiple MBOMS easier to deal with.
- The PLE reads the EBOMS and MBOM Headers and components including Instance-based data to ensure that we know the location of each CAD instance in the build process. This ensures that ECO changes affecting only partial quantities of a Part Number are properly processed.
Stage 4: Leverage your PLM data Links to facilitate Process specific visuals

- Process Specific Visuals are Time-Consuming to Create and keep current. They are usually:
  - Sketches
  - Photos
  - Model-Based Views
  - Multi-Page PowerPoint or Word Docs
- They become obsolete almost as soon as they are birthed…
- Using Model-Based tools to auto-create process Visuals saves time and eliminates errors. They require process steps with assigned components. The PLE provides a framework for creating these process recipes in order to generate Model-Based Visuals automatically for new processes and Modified Processes after ECOs.
The PLE Integration Bridge offers Standard Interfaces to PLM and ERP to facilitate growing and sustaining the Digital Thread

**PLM**
- Process Plan (BOP)
- Process 3D Views
- Product Characteristics
- ECN
- ECN Status Update
- WO Status Update
- Non-conformance to Problem Report
- Disposition/Deviation Approval
- Corrective Action Item to ECR

**Enterprise Service Bus**
- Process Change Management
- Process Execution
- Discrepancy Handling
- Part-No (pass-thru)
- BOM (pass-thru)
- Process Routing
- Work Order Release
- Work Order Operation Status
- Work Order Operation Schedule
- Work Order Revisions
- Parts Issue to WO Operation
- Defects, Scrap, Returns

**PLE**

**ERP**
- Parts, Production Routings
- Order Fulfillment & Scheduling
- Procurement, Inventory and Supplier Management
THANK YOU

QUESTIONS?