Systems Engineering Integrative Project

Part Marking, Serialization, & Traceability

Loyola Marymount University – Graduate School of Engineering
Systems Engineering Integrative Project

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Lloyd Williams

Presentation Outline

• Foreword
• Introduction
• Project Topic – Criticality Traceability
• Issues Encountered
  – Data Analysis
• Systems Engineering Principles
• Requirements Development & Allocation
• Integration, Verification, & Validation
• Risk Management
• Conclusion
• Reference
Foreword

• Academic Background
• Work Experience
• Current Position
• Integrative Project Concept

Acronyms

• ASNR  Accessory Serial Number Record
• ALOO  Assembly Line Order Operation
• DADT  Durability and Damage Tolerance
• BTP   Build-to-Package
• NL    Notes List
• FC    Fracture Critical
• PCS   Flight Science Critical
• MC    Maintenance Critical
• DC    Durability Critical
• SC    Safety Critical
• MAC   Mission Abort Critical
• ME    Manufacturing Engineer
• MRB   Material Review Board
• IMPCA Integrated Management Planning and Control for Assembly
• MES   Manufacturing Execution System
• CPI/OS Contract/Production and Inventory Optimization System
• PDM   Product Data Manager
• OASIS Online Automated Supplier Information System
• SQUID Store and Query Unique Identification
• Livelink System used to review manufacturing plans
Integrative Project Experience

• Purpose: To use systems engineering to develop a system that would allow NGC to have 100% traceability on all critical and UID mandated parts.

• Research was conducted using the SE principles most applicable to software integration

• The report demonstrates how these recommendations would allow NGIS to meet current DoD mandate MIL-STD-130L and assist in meeting program schedules and budgets throughout the program lifecycles.

Integrative Project Concept

• The original project envisioned was one that looked at manufacturing's role within the current system used to identify critical parts and reducing the non-value added work associated with it. Manufacturing is required to log on to IMPCA and record the serial numbers of all the traceable parts. At a production interval of one air vehicle per day this would put a non-value added cost and negative cycle time impact on the program. But, after looking at the system it was apparent that the entire system, not just the manufacturing portion was in need of repair.
**Aircraft Serial Number Report Log Issue**

**Issue:** Aircraft Serial Number Report log (ASNR) is still unusable. Currently the only numbers tracked via the Engineering critical list are fracture critical traceable. This list has changed many times. No hydro, fuel or electronic components are listed as requiring serial numbers verification.

**Currently:** Inspection has been keeping an Excel spread sheet of serialized parts installed on units at PMC. Form 27-835 is also filled out only if the plan has this requirement. This form is then sent to closed records. At delivery the forms will need to be pulled and checked to the Excel list to ensure parts have not been removed and replaced for some recall or MRB action.

**Impact:** If parts were to be placed on recalled NGC would not know what unit the part was installed on. This could possibly ground the fleet or require hours of maintainer investigation.

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**Current System - Risk**

- DoD mandate requiring all defense contractors to serially label every component and subsystem not being met.
- Parts not identified as traceable
- Parts not included in list for supply to know what is traceable, what should be included in the air vehicle, and what should be shipped loose.
- Multiple suppliers providing the same part configuration and duplicate a serial number
- Serial numbers transposed or repeated
- Cost of program escalating based on having to input serial numbers into IMPCA, and also searching for parts (schedule impact)
Summary of Fracture Control Process

SUMMARY OF FRACTURE CONTROL PROCESS

PREPARE DADT REPORTS
- REQUIREMENTS
- ANALYSIS METHODS
- TEST PLANS
- DATA COLLECTION & CONTROL
- DESIGN GUIDELINES

PREPARE DADT CONTROL PLAN

PREPARE LISTS OF APPROVED:
- MATERIALS
- PROCESSES
- FASTENERS
- STANDARD PARTS
FOR USE WITH F/D CRITICAL STRUCTURE

SELECT AND LIST CRITICAL STRUCTURE

CONDUCT DADT ANALYSES AND TESTS

CONSIDER F/D CRITICALITY IN DESIGN CHANGES AND MFR ACTION

PREPARE FRAC TURE CONTROL SPECIFICATIONS

SELECT AND LIST CRITICAL STRUCTURE SPECIFY FRAC TURE CONTROLS ON ENGINEERING DRAWINGS

PREPARE MANUFACTURING WORK INSTRUCTIONS

CONDUCT DADT ANALYSES AND TESTS

IMPLEMENT FRAC TURE CONTROLS FOR IN-HOUSE ASSEMBLY AND PRODUCTION

AUDIT VENDORS FOR ABILITY TO PRODUCE F/D CRITICAL PARTS AND MATERIALS

INCLUDE FRAC TURE CONTROL REQUIREMENTS IN QA AND MFR PLANS

PREPARE FRAC TURE CONTROLS IN VENDOR PRODUCTION PLANS FOR CRITICAL MATERIALS

UPDATE F/D CRITICAL COMPONENTS IN SERVICE USAGE

IMPLEMENT FRAC TURE CONTROLS IN VENDOR PRODUCTION OF F/D CRITICAL PARTS AND MATERIALS

**Process Flow to Determine ASIP Part Marking Requirements and BTP Associated Impacts**

Part Effective for 2BF-1 & on; 2AF-1 & on; 2CF-1 & on;

Is part ASIP Criticality and Trace Type correct in PDM? No

Is part already released? No

Yes

Identify impact and collect with other identified impacts for CR submittal

What is part ASIP Criticality? No

Fracture Critical/ Material Traceable (FC MT)

Fracture Critical/ Non Traceable (FC NT)

Maintenance Critical/ Material Traceable (MC MT)

PDM

Update PDM

Criticality to Fracture Critical and Trace Type to Material or Lot Traceable

Update PDM Criticality to Fracture Critical and Trace Type to Non Traceable

Update PDM Criticality to Maintenance Critical and Trace Type to Material or Lot Traceable

Detail

Next Assembly

Face of Drawing

Update F/D with appropriate note (Ref. PM-4052 Section 03:16.19.10)

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ASIP Stress Analyst/ DADT Analyst

Ref: SEI-1088
Process Flow to Determine ASIP Part Marking Requirements and BTP Associated Impacts

Part is Effective for 2BF:1 & on; 2AF:1 & on; 2CF:1 & on.

- What is part ASIP Criticality? CR
- ASIP/ Stress Analyst/ DADT Analyst
- Coordination Notification
- Update PDM
  - Maintenance Critical/ Non Traceable (MC NT)
  - Normal Controls/ Non Traceable (NC NT)
- Update PDM Criticality to Maintenance Critical and Trace Type to Material or Lot Traceable
- Face of Drawing
  - Update F/D with appropriate note (Ref. PM-4052, Section 03-16.10.10)
  - Remove F/D note if previously captured for incorrect criticality assignment

Face of Drawing

Next Assembly

Update F/D with appropriate note (Ref. PM-4052, Section 03-16.19.10)

Remove F/D note if previously captured for incorrect criticality assignment

Ref: SEI-1088

Process Flow to Determine MESIP Part Marking Requirements and BTP Associated Impacts

Part is Effective for 2BF:1 & on; 2AF:1 & on; 2CF:1 & on.

- Is part MESIP Criticality and Trace Type correct in PDM? Yes
  - Are F/D notes correct for detail part? Yes
    - No action required
  - Are F/D notes correct for next assembly? No
- Is part an Airframe part? Yes
  - Identify impact and collect with other identified impacts for CR
  - No
- Is part already released? No
  - Coordinate with responsible team to address detail part changes
- What is part MESIP Criticality? CR
- MESIP/ Stress Analyst/ DADT Analyst
- Coordination Notification
- Update PDM
  - Safety Critical Installation Traceable (SC IT)
  - Safety Critical Material Traceable (SC MT)
  - Safety Critical/ Non Traceable (SC NT)
- Update PDM Criticality to Safety Critical and Trace Type to Installation Traceable
- Update PDM Criticality to Safety Critical and Trace Type to Material or Lot Traceable
- Update PDM Criticality to Safety Critical and Trace Type to Non Traceable
- Update F/D with appropriate note (Ref. PM-4052, Section 03-16.19.10)
- Update F/D with appropriate note (Ref. PM-4052, Section 03-16.19.10)
- Update F/D with appropriate note (Ref. PM-4052, Section 03-16.19.10)

Ref: SEI-1088
Process Flow to Determine MESIP Part Marking Requirements and BTP Associated Impacts

Note: It is the responsibility of the owning team (AF, MS, VS, WI) to place the appropriate PDM attributes and face of drawing notes on the detail parts. AF teams have the responsibility of addressing the next assembly or installation PDM attributes and face of drawing notes.

Current System (1 of 2)

- Currently no single system exists within NGIS that will provide 100% traceability from supplier to transfer to prime.

- These are incapable of providing the breadth and depth of functionality required to meet DoD Mandates.

- NGIS' current environment consists of legacy systems and manual operations.
Current System (2 of 2)

- The SE Integrative Report focuses on Critically Traceable parts from design to final delivery to the customer (LM Aero) and parts needing DoD UID.
- There were issues involved with some of the team members in each step that resulted in the last air vehicle delivered to have a total of 64 parts unaccounted for.
- The resultant failures of each team along the way has the potential of slowing down the program and hurting future programs.
- The failures also have the ability to create on impact in both schedule and cost.
  - Time spent resolving and correcting the errors
Issues Encountered (1 of 2)

• There is no automatic trigger to the subsystem IPT members and downstream members to let them know that the part is critical
• No documented process to tell that a part is critical until that part has been designed.
• Process not formerly documented for Subsystems
• Subsystems items are being recorded on paper rather than putting them in the system.
  – no requirements to place criticality on drawings

Issues Encountered (2 of 2)

• Prime contract spec is not being met, waiver for SDD.
• Design is not putting the Criticality on the drawing
• (ME uses the drawing to alert them that the part is critical so that they can flag the ASNR)
• Majority of ME’s do not know that they are supposed to be flagging for an ASNR
• ME’s are finding ASNR’s are not loaded in IMPCA
• Suppliers - no requirements for them to mark the part criticality
• Manufacturing - no trigger (drawing is the trigger - but no criticality is listed on the drawing)
Unique Identification

Definition
- The DoD vision for unique item identification is to implement policy, regulations, and supporting processes that establish a strategic imperative for uniquely identifying tangible items. Uniquely identified tangible items will facilitate item tracking in DoD business systems and provide reliable and accurate technical and financial data for management, financial accountability, and asset management purposes.

Timing (no later than)
- Have program implemented for LRIP 1 (2AF:5, 2BF:5, 2CF:4)

Affects and Effects
- Detail parts and Next Assemblies/Installations
- Dataset Notes required
- PDM attributes selection required

Status
- Definition of affected parts described by a parts and spares list (2YZA00104 and spares list).
- Dataset notes available (PM-4052 3-16.19.8)
- PDM attributes not available (available April 2007)
- Not All Parts correctly marked and PDM attributed selected

Path Forward
- Air Vehicle Project Engineering requested to produce CR for Released items
- Airframe IPTs to apply 2YZA00104 and spares list for all new releases/touched datasets
- Airframe to use CR to correct previously released engineering
- Part number rolls required to correct Dataset Markings
- Part Number rolls not required for PDM attribute correction
**DoD UID Requirement Flow Chart**

**Initial Design** Example Process Flow to Determine Unique Part Identification Marking Requirements and BTP Associated Impacts

1. Dataset is Effective for B6-6-9999, AF-6-9999, CF-6-9999
2. Has the part been designed to be removed and replaced (come on and off) on the aircraft?
3. Assembly/Install contains a part that has UID serialization requirements? (check PDM attributes)
4. Is the part on the UID Parts List?
5. Is the part cost over $50/Unit?
6. Part requires UID Marking Required. See PM102 3-16.12.8
7. Cost Accounting Input (Fully burdened cost)
8. *Contract/ Sub Contract and Exhibit line items*

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*Commercial Item Identification examples are the Universal Product Code and Health Industry Bar Code*
Notes PM-4052 3-16.19

<table>
<thead>
<tr>
<th>Type</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detail</td>
<td><strong>THIS PART IS HAS UID</strong> BAR CODE PART WHERE SHOWN PER 2ZZP00008, CLASS X Y [X = CLASS 1 OR 3] [Y = METHOD A, B, C, D, E OR F], TYPE XX-2 [XX = 01, 03, 04, 05, 06, OR 07].</td>
</tr>
<tr>
<td>Assembly</td>
<td>THIS ASSEMBLY CONTAINS UID, BAR CODE PART WHERE SHOWN PER 2ZZP00008, CLASS X Y [X = CLASS 1 OR 3] [Y = METHOD A, B, C, D, E OR F], TYPE XX-2 [XX = 01, 03, 04, 05, 06, OR 07].</td>
</tr>
<tr>
<td>Installation</td>
<td>THIS INSTALLATION CONTAINS PARTS/ASSEMBLIES CONTAINING UID.</td>
</tr>
</tbody>
</table>

Identification Method

- 2-D Data Matrix Barcode
  - "damage tolerant"
  - contains redundant data
  - allows for readability of marks damaged up to approximately 25%.
  - allows up to 2,000 characters to be contained in a code that can be as small as one-tenth of an inch square
**Missing ASNR Log Investigation**

-BTP NL (Notes List) callout drives ME requirement to code part in Impca for ASNR log creation

**Missing ASNR Log Investigation**

-ME codes part as "F" in ASNR field on PCS/Allo record 6; This particular part is coded at the assembly installed level for the recording of the detail; There are instructions in Allo record 8 for the mechanic specifying this.
Missing ASNR Log Investigation

• ASNR screen for BF1; This is the all up viewed from QA screen
• Of the (9) ASIP parts requiring ASNR Log, (5) were correctly done while (4) are being investigated
• MESIP parts missing ASNR Log are still under investigation

Immediate Corrective Action

• Quality Ensure Serial Numbers of Parts on ASIP and of Systems Parts Carrying Serial Numbers Physically Are Recorded on ALOO Face of Work Instructions if ASNR Log Does Not Exist at Time of Installation.

  - Form 27-835 is Being Filled Out by QA if Work Instructions Call Out and Carry Recording on Face of ALOO Work Instructions
  - ME Ensure IMPCA is Functioning Appropriately for ASIP (FCT, SCT) Parts
  - QA Supply List of Serialized Parts for ASNR Master/ASNR Review
  - ME/IT Drive Serialized Parts Data Back into .XML (As-Built BF1) File Using Excel Spreadsheet
  - ME/CM Review BTP NL of (4) Missing ASNR Log Parts on BF1
Meeting The Requirements

- Integrate all legacy databases and systems pertinent to traceability and UID and bring web capabilities using Java 2 Platform Enterprise Edition (J2EE) or Microsoft .NET framework.
- Provide a means of automatically identifying critical parts and parts requiring UID and tracking it throughout its build and installation process.
Key Features of System to Meet Requirements (1 of 2)

- Uses open standards
- Web-based and easily viewable
- Ties all legacy databases and systems
- Automatically produces an UID per DoD Flow matrix
- PC Based
  - PC processors have become fast enough to perform mainframe emulation
- N-Tiered
  - Any one tier can run an appropriate processor or operating system platform and can be updated independent of other tiers
  - More robust and eliminates single point of failure

Smart Proxy for Legacy System

- Many legacy systems were not built with features such as Return Address
- "wrap" access to the legacy system with a Smart Proxy
  - Enhances the basic system service with additional capability so that it can participate in a Service-Oriented Architecture.
  - Intercepts messages sent on the request channel to the Request-Reply service.
  - For each incoming message, the Smart Proxy stores the Return Address specified by the original sender.
  - It then replaces the Return Address in the message with the channel the reply channel that the Smart Proxy is listening on.
  - When a reply message comes in on that channel, the Smart Proxy retrieves the stored Return Address and uses a Message Router to forward the unmodified reply address to that channel.
Key Features of System to Meet Requirements (2 of 2)

- Web Based Service Oriented Architecture
  - Respond quickly and cost-effectively to changing conditions
  - Simplifies interconnections to and usage of existing legacy systems

- Use SQL
  - Allow for automated database replication
  - High reliability
  - Highly secure

- Virtual Private Network
  - Ride on current NGC network using guard technology to communicate between Suppliers, Prime, Partners, and DoD systems.
System to Meet Requirements Risk

- Integration of legacy systems
- Reliability of Proposed System
- Security of Proposed System

Trade-Off

- System must meet three criterion:
  - Ensure that the part is marked per DoD mandates
  - Have the ability to track the parts and give it’s current location
  - Give the history of all traceable parts from raw stock to final delivery.
- WhereNet System
- Lasers (Fiber vs. Diode)
- In-House vs. Contract
System to Meet Requirements

Value Stream Map for Serialization and Traceability System

System Interfaces

- Operate within the context of the Federal Enterprise Architecture
- Data sharing and application interfaces be accomplished through the use of a common service layer such as Data Access Agents (DAA).
- Interface Definition Language (IDL) scripts can be tailored to do specific tasks in order to implement the DAA through the use of Common Object Request Broker (CORBA).
- The capabilities that can be utilized for interfacing include the following:
  - Files (XML, CSV, etc)
  - Database Tables
  - Dynamic Data Exchange
  - Mail Messages
  - RS-232 Serial Communications
  - Import / Export Files
  - Dynamic Link Library
  - External Program Execution
  - FTP
  - TCP / IP Sockets
  - OLE Automation, ActiveX
Validation & Verification

• Test methodology should support a building block process for the integration of the systems.
• Serial approach with strict entrance and exit criteria building upon each other
  – Progress from unit-level testing through subsystems testing and into integration of third-party COTS products
  – Culminating in a system-level test incorporating all external interfaces.
• Firm requirements baseline with clear measures of success for each test and each phase in the test process.
  – The tests should replicate the operational environment and run and pass at peak demands scenario prior to acceptance.
  – There should be strict entrance and exit criteria for each test
  – The baseline should be held firm and not change with software modifications
  – Live interfaces must be tested at both the functional and technical levels

Example of System for Meeting Requirements

LIGHTNING II
F-35
### F-35 Schedules

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Info</td>
<td>CPDIS part numbers and serial numbers</td>
</tr>
<tr>
<td>PHDS</td>
<td>Delivery dates and critical path flow</td>
</tr>
<tr>
<td>Line Move Schedules</td>
<td>SWBS Start and Finish dates</td>
</tr>
<tr>
<td>Line Move Delays</td>
<td>Start date delta to prior schedule</td>
</tr>
<tr>
<td>Paint</td>
<td>Paint Schedule</td>
</tr>
<tr>
<td>Historical Comparisons</td>
<td>Rate Build Up Comparison</td>
</tr>
<tr>
<td>SDD Waterfall</td>
<td>F-35 SDD Center Positape Master schedule</td>
</tr>
<tr>
<td>Traceability</td>
<td>SDD SWB Level Dates in Excel Format</td>
</tr>
<tr>
<td>SOD</td>
<td>The SWBS dependencies and Tooling elements</td>
</tr>
</tbody>
</table>

#### Generic Assembly Flow

| AA-1                  | 0.0-.911          |
| BF-1 to BF2           | 2.9-.911          |
| BF-3 to AF-2          | 5.9-.211          |
| AF-3 to BF-5          | 8.9-.411          |
| F-4 R08              | 8.5-.811          |
| HSC to U3A           | 8.5-.611          |

#### Type Version

<table>
<thead>
<tr>
<th>Type</th>
<th>Version</th>
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<tbody>
<tr>
<td>STOW</td>
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<tr>
<td>CTOL</td>
<td></td>
</tr>
<tr>
<td>CV</td>
<td></td>
</tr>
</tbody>
</table>
## F-35 Master Scheduling

### Locations
- El Segundo
- M/S Building
- Site 4, Building 401: 1st Floor
- Site 4, Building 411: 1st Floor

### Type Version
- STOVL
- CTOL
- CV

### Table
<table>
<thead>
<tr>
<th>Type Version</th>
<th>Effectivity</th>
<th>Part No.</th>
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<tr>
<td>STOVL</td>
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<td>XXXX</td>
<td>XXX</td>
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<tr>
<td>CV</td>
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<td>XXXX</td>
<td>XXX</td>
<td></td>
</tr>
</tbody>
</table>

- Normal
- Fracture
- Durability
- Maintainability
- Mission Abort
- Safety of Flight
Conclusion

• The issues facing Criticality Traceability came in many different forms and for varying reasons
• The current use of ad-hoc systems is not sufficient to ensure the capture of all critical traceable parts
  - 44 part numbers that were not accounted for and 20 that were not included in IMPCA
  - Currently there are 16 parts on air vehicle BG-1 that can not be located. The proposed system has the ability of integrating legacy applications or presenting correlated data from distributed databases.
  - The system also brings capabilities such as managing workflows, increasing collaboration between work groups
  - Allow internal and external access to specific corporate information using secure authentication or Single-Sign-On.
  - Provide 100% traceability from raw stock to delivery

Reference (1 of 2)

STANDARDS AND GUIDELINES

• W3C. Web content accessibility guidelines 1.0 Cambridge, MA [?]: W3C, 1999. Available at http://www.w3.org/TR/WCAG10/
• DFARS 252.211-7003(a) - Item Identification and Valuation
• ISO 15415 - Information technology — Automatic identification and data capture techniques — Bar code print quality test specification — Two-dimensional symbols
Reference (2 of 2)

NGIS DOCUMENTATION

- Systems Engineering Instruction - Subsystem Equipment Criticality Management, 8 June 2006
- Systems engineering Instruction - Traceability of Air Vehicle Components, 7 September 2006
- Aircraft Structural Integrity Program (ASIP) Master Plan (MESIP)
- Safety Critical Functions List
- General Specifications for Control of F-35 Vehicle Critical Parts, 17 October 2006
- Subsystem Critical Parts List
- JSF Durability and Damage Tolerance Control Plan
- Business Area Procedure - F-35 Traceability of Critical Parts and Materials, 22 June 2004
- Business Area Procedure - Unique Identification of Aircraft Items