Paperless Harness/Cables Fabrication

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Abstract *— This project focused on Paperless Harness/Cables Fabrication for Documentation Control in an aerospace company. Documentation control improves paperwork handling, the gathering and filling of all the documentation required for the Harness/Cable Build.*

In order to improve documentation handling, the Lean Manufacturing methodology will be used. Lean Manufacturing's goal is to eliminate waste—the non-value-added components in any process. This research will be focused on eliminating waste using the Lean Manufacturing 5S principle to improve the cleanliness and organization of the workspace. 5S concepts include the following definitions: sort, simplify, shine, standardize, and sustain.

This research seeks to implement the Paperless Work Order Traveler of Harness/Cables Fabrication. This is important for the process because it will add Fabrication status visibility to the internal customer, reduce/eliminate the waste of paper in the fabrication area, reduce/eliminate the loss of documentation, standardize the process, and improve the space in the work station, clean area.

Lean Manufacturing methodology brings structure and tools to improve a process by standardizing and improving the process in, in this case, paperless Harness/Cables Fabrication in an aerospace company.

Key terms *— harness/cable fabrication, paperless, standardization, work orders*

INTRODUCTION

For many years, this aerospace company has provided critical contributions to critical challenges. The company is not a mass production manufacturing company and the process is manual (such as hand-crafted); at the end the result is magnificent. The company needs to stay competitive, reducing and/or eliminating all the processes that are affecting negatively time and effectiveness of the harness/cable fabrication.

This research project will be focused on a Paperless Harness/Cable Fabrication that will help the company to standardize its process and add fabrication status visibility to the internal customer.

Problem Statement

The Fabrication Laboratories are running the build using hard copies of the Work Order Traveler while the I&T team is using Paperless Work Orders. At the moment, we are running the operations using two different processes. With the standardization of the process (Paperless Work Orders), we can correlate Work Orders between fabrication and the Final Test (I&T), and we can improve the organization of work stations and documentation loss. In order of achieve this goal, the Lean Manufacturing project methodology and 5S concept are going to be used.

Research Description

This research is about Paperless Harness/Cables Fabrication. This is important for the process to standardize process, add fabrication status visibility, workstation organization, document control and reduce/eliminate waste of paper.

Research Objectives

This project aims to achieve Database standardization. This will add visibility to the fabrication process and correlation between the Work Order Fabrication and I&T Work Orders.

Research Contributions

This project seeks to keep all Fabrication Documentation in the same I&T Database.

Reducing paper usage will contribute to the company's:

- Prevention of loss information
- Accountability: changes will be added in real time in the Work Order Travelers.
- Reduction of miscommunication
- Improvement of processes
- Recording of relevant data
- Reduction wasted time

Literature Review

It is the policy of the company to attain quality in all of its work products. The company defines quality as fitness for use and satisfaction of sponsor requirements. [1] As applied to the company works, fitness for use means that it will meet sponsor expectations for product capability and performance, meet schedule, and meet budget. All staff members are responsible for the quality of work within their purview. The quality philosophy governing the manner in which the Company performs its work is described in the Company Quality Policy: "Across the Company critical contribution are made to critical challenges through the applications of science and technology. The Company strives for excellence in all the Company does, performing the work with quality and integrity. All products of the Company sponsors meet requirements for intended use as well as schedule and cost. The Company is committed to continual improvement. To implement this policy, the Company has developed the Quality Management System (QMS)." [1]

The application of the QMS is scaled according to task characteristics such as complexity, visibility, risk, and intended use.

The quality Manual has the Control Records section, on which this project is focused.

RIM (Records and Information Management) is the effort that the company is working on. Records are one of the most valuable assets of the company. The company is focused on the following:

- Improving efficiency and access to information.
- Minimizing storage requirements and reducing clutter.
- Enabling information re-use and knowledge sharing.
- Meeting compliance obligations and minimizing risk.
- Protecting sensitive information.
- Ensuring that permanent and historical records are available for future research.

The AS9100 standard [1] provides the requirements for establishing and maintaining a quality management system for the aerospace industry. The quality management contain a section dedicated to Quality-Control Records: "As part of the overall enterprise Record Management Program, the company maintains records to support the effective operation of the Quality Management System (QMS). The specific controls outlined in these sections include identification, storage, protection, retrieval, retention, disposition of required records in support of the associated requirements of the QMS." [2]

The company performed internal audits to review the requirements of AS9100. The purpose of this is to verify compliance of the organization's quality management system with the AS9100 standard.

The Quality Management System is divided into five main sections that state requirements for the primary process "categories" in the company. The category in which the project was focused is quality management system processes, including developing the QMS documentation, control and records control. [1]

General Concepts of the Lean Manufacturing Methodology

Lean Manufacturing, a process that originated in Japan decades ago, is widely embraced by manufactures today as a way to eliminate waste from manufacturing operations. The five steps thought process for guiding the implementation of lean techniques are: [3]

- **Identify Value:** Always defined by the customer's needs for a specific product.
- **Map the Value Stream:** A simple but eye-opening experience that identifies all the actions that take a product or service through any process. The goal is to identify every step that does not create value and then find ways to eliminate those wasteful steps.
- **Create Flow**: This part evaluates that the remaining steps run smoothly with no interruptions or delays toward the customer.
- **Establish Pull:** The product or service can be delivered just in time after the process runs smoothly.
- **Seek Perfection:** Mindset change. Maintain the changes and continue process improvement.

Lean uses a number of practices; the one that will be used in this research project will be 5S. [1] [4]

5S (Sort, Set in Order, Sweep, Standardize, and Sustain) (figure 1) is designed to keep a workplace safe, clean, and organized to save time and optimize efficiency. A very visual system, 5S optimizes work standardization efforts and productivity.

- **Sort**: Clearly distinguish needed items from unneeded items and eliminate the latter.
- **Simplify (also known as Set in Order):** Keep needed items in the correct place to allow for easy and immediate retrieval.
- **Shine:** Keep the work area swept and clean at all times.
- **Standardize:** Standardize cleanup (the first three Ss),
- **Sustain (also known as Self-Discipline):** Make a habit of maintaining established procedures.

Figure 1
Lean Manufacturing 5S

PROJECT METHODOLOGY

A systematic approach needs to be used as a methodology to achieve the goals of the project. Since the purpose of the project is reducing/eliminating, paper usage is the first step to cutting waste and adopting lean manufacturing principles.

Also, the 5S methodology will be used in this project to keep the area paperless, clean, and organized.

The Lean Manufacturing methodology will help us eliminate the Non-Value-Add (waste) in the process.

Results and Discussion

The results obtained through the five phases of the Lean Manufacturing methodology are as follows.

- **Identify Value:** As part of the project, definition the following was performed in order to determine the area to be improved, the goal of the project, and the metrics that will be defined. In this research, we are focusing on paperless.
    - **Goal #1:** Evaluate whether the company's subsystem-level fabrication activities

should move from a paper-based system to a paperless system

- **Goal #2:** Evaluate options for a paperless system and determine the best fit for the company's subsystem-level fabrication activities.
- Possible fabrication activities to consider:
  - Flight harness assembly
  - Required Quality Department inspections
  - Calibrated equipment
  - Specific forms to be completed
  - GSE harness/cable assembly
  - Just require peer inspections
  - GSE rack assembly
  - Engineer inspection

The new system will be implemented prior to start of the selected project on June 2022.

The current fabrication work instructions are shown in figures 2 to 6.

Work Order Traveler (WOT) Sheet 1 of 18

Title	Program	WO#	Date
DART, J-Side Bulkhead Connector Terminations	DART	DART-FM-021	12/24/2019
Originator	**Requirements / Comments**	**Drawing No. ***	**S/N***
Kyle Norman Harness Lead Engineer	NASA-STD-8739.4	7482-8001	
Lead Engineer Signature	**Systems Assurance Signature**	**Cognizant Engineer Signature***	
APPROVED By Kyle Norman at 12:18 pm, Dec 24, 2019	APPROVED By Cindy K. Kim at 3:11 pm, Jan 02, 2020		

* If Required

Step Number	Description	Initials	Date	Notes
10.0	Lead Assembly Technician to review this WOT with latest revision of drawing released on PLM, prior to performing work. All steps in this WOT, with exception to the last step, may be completed out of sequence.	RA	3/3/2020	

Figure 2
Work order example

30.0	Twist and label prewired MDM connectors for P3203 and P3803 per 7480-8902 section 4.4.4 and drawing 7480-8001 rev C sh. 29 & 30.	CD	1/7/20	
40.0	Install prewired MDM connectors for P3203 and P3803 per drawing 7480-8201 rev C routing and 7480-8001 rev C sh. 29 & 30 pinouts. Use colored cable ties to match drawing bundle color. Verify that insulation does not have nicks, cuts, or tears and that conductor strands are in the appropriate lay position and there are no residual twists or kinks from twisting. Coil unterminated wires and secure out of the way.	CD	1/20/20	

Lead Engineer Signature: Jack Perry	**Date:** 01/27/2020
Systems Assurance Signature:	**Date:** 1/29/2020
After this Work Order has been signed by the Lead Engineer and the Systems Assurance Manager, the document should be scanned (if applicable) and placed in the archive.	**Close-Out Date:** 02/03/2020

SD-QP-631-4M-01
June 20, 2019

Figure 3
Work order example

Work Order Traveler Sheet 1 of 2

Title	Program	WO#	Date
DART_I&T_PMU/PSCU GSE Cable	DART	DART_I&T_WOT_W016	7-16-19
Originator Michael Colby	**Requirements / Comments** IK503A32	**Drawing Number:** (if req'd) 7482-7216	**S/N:** (if req'd) 1
Lead Engineer Signature APPROVED By Colby, Mike at 9:07 am, Jul 16, 2019	**Systems Assurance Signature**	**Cognizant Engr Sig** (if req'd)	

Step Number	Description	Initials	Date	Notes
10.0	Assembly technician to review this WOT with drawing prior to performing work. Steps may be completed out of sequence.	T. Humphry	7-17-19	
20.0	Review drawing. Compare drawing to W041. Verify part numbers, identify part shortages, and visually inspect parts.	T. Humphry	7-17-19	
	W016 Steps			
30.0	Modify PSP W041 per 7216 drawing.	T. Humphry	7-17-19	
40.0	Unpin unused contacts and shrink tube. Extra connector can be tied back.	T. Humphry	7-17-19	* removed them 7/17/19

Figure 4
Work order example

TENSILE STRENGTH TEST DAILY LOG

Date: 3/5/2020 ☒ Begin Shift ☐ End Shift Work Order #: DART-FM-021

Project/Program: DART

Fabricator: Rob Aumiller

Inspector: Tammy

Tensile Tester:

JHU/APL #: 283047

Calibration Date: 10/22/2019

Recalibration Date: 10/31/2020

Crimp Tool Data:

JHU/APL #: 319698

Calibration Date: June 13, 2019 Due: June 30, 2020

* Location of Break:

(a) Break at Crimp
(b) Break Outside of Crimp
(c) Fray Break
(d) Pull Out

Connector Reference Number: J5004, J5104

Wire Size	Contact Size & Gender	Positioner & Setting/Color	Operator		Tensile Strength Test				Inspector	
			Init.	Date	Pull Rate (in/min)	Gage Read (lbs)	Loc. Of Break (*)	Min Force (lbs)	A Accept R Reject	Init.	Date
2 wires common											
WIRE 1	26	22P K42 #3	RA	3/5/2020	1.0	13.5	A	8.0	A	YB	3-6-2020
	26	22P K42 #3	RA	3/5/2020	1.0	16.8	A	8.0	A	YB	3-6-2020
	26	22P K42 #3	RA	3/5/2020	1.0	13.8	A	8.0	A	YB	3-6-2020
	26	22P K42	RA	3/5/2020	1.0	15.5	A	8.0	A	YB	3-6-2020

Figure 5
Form example

Work Order Traveler (WOT) – Fabrication Tracking Sheet 2 of 4

1. WOT Number: DART-FM-021 NOTE: EMPTY SPACES INDICATE STEP IS NOT REQUIRED AND DOES NOT APPLY

2. Connector Reference	Shield Termination 3. Shield Termination Tech. QA	4. Shrink Tube Tech. QA	Crimp Contact Connectors 5. Crimp Contact Termination Tech. QA	6. Contact Insertion Tech. QA	7. Crimp Contact Retention QA	Solder Contact Connectors 8. Solder Termination Tech. QA	9. Shrink Tube Tech. QA
J5302	RA 3/3/2020 YB 3-6-2020	RA 3/6/2020 YB 3-6-2020	RA 3/5/2020 YB 3-6-2020	RA 3/11/20 YB 3-12-2020	YB 3-12-2020	N/A	N/A
J5303	N/A	N/A	RA 3/5/2020 YB 3-6-2020	RA 3/11/20 YB 3-11-2020	YB 3-11-2020	N/A	N/A
J5305	N/A	N/A	RA 3/5/2020 YB 3-6-2020	RA 3/11/20 YB 3-11-2020	YB 3-11-2020	N/A	N/A
J5306	RA 3/3/2020 YB 3-6-2020	RA 3/6/2020 YB 3-6-2020	RA 3/5/2020 YB 3-6-2020	RA 3/11/20 YB 3-11-2020	YB 3-11-2020	N/A	N/A
J5307	N/A	N/A	RA 3/11/2020 YB 3-11-2020	RA 3/11/2020 YB 3-12-2020	YB 3-12-2020	N/A	N/A
J5309	RA 3/3/2020 YB 3-6-2020	RA 3/6/2020 YB 3-6-2020	RA 3/5/2020 YB 3-6-2020	RA 3/11/2020 YB 3-11-2020	YB 3-11-2020	N/A	N/A
J5310	N/A	N/A	RA 3/5/2020 YB 3-6-2020	RA 3/11/2020 YB 3-11-2020	YB 3-11-2020	N/A	N/A
J5101	RA 3/3/2020 YB 3-6-2020	RA 3/6/2020 YB 3-6-2020	RA 3/5/2020 YB 3-6-2020	RA 3/11/2020 YB 3-11-2020	YB 3-11-2020	N/A	N/A
J5102	RA 3/3/2020 YB 3-6-2020	RA 3/6/2020 YB 3-6-2020	RA 3/5/2020 YB 3-6-2020	RA 3/11/2020 YB 3-11-2020	YB 3-11-2020	N/A	N/A

Figure 6
Form example

- **Map the Value Stream**: The current process is consuming a high amount of paper to fabricate harness/cables in the fabrication area. Paper waste is too high; we are focusing this project to reduce it.

    - Paper waste
    - Waste of technician's time: printing copies, walking to get the papers printed
- **Create Flow**: Evaluating that remaining steps flow smoothly with no interruptions or delays for the customer.
- **Establish Pull**: The results of this research will be validated on phase II, during the implementation of the project. Our expectations are that the process will run smoothly and without interruption.
- **Seek Perfection**: The process has been run using paper for a long time. We have been discussing the benefits of paperless fabrication of the Harness/Cables and improvement of efficiency during fabrication. Also, we show the simplicity of the system, how clean the area will look after the paperless implementation. The expectation in phase II is to reduce the use of paper by 90%. Phase III will evaluate how to link all the forms required to build the Harness/Cable, monitors to project the drawings, and any other equipment or software change to be 100% paperless.

EVALUATION

- Stakeholders
    - Technicians
    - Manufacturing engineering
    - Harness engineers/designers
    - Harness routing engineers/designers
    - SMA (quality)
- Some potential evaluation criteria (a starting point)
    - Technician usability
    - Engineer/author usability
    - Flexibility (redline/blackline, steps out of sequence, etc.)
    - Compliance with SMA/CM requirements
    - Data entry methods (barcode scanners, etc.)
    - Links to parts system
    - Links to harness 3D CAD routing design
    - Manufacturing data capture (durations, workloads, etc.)
    - Links to nonconformance tool

The following databases were evaluated:

- VE
- EPIC (Electronic Product Information Centre)

A trade study will potentially expand these options, along with further detail on the advantages/disadvantages of each.

- EPIC Database
    - Advantages
        - User-friendly
        - Documentation can be loaded in the database
            - Material record
            - Tools record
        - Simple database
        - It can be linked with the database that has the Bill of Materials as a placeholder for BOMs.
    - Disadvantages
        - Cables/Harness build cannot be scheduled
        - No part traceability
    - To be evaluated with EPIC
        - Schedule to be added to the system
        - Parts traceability linked with VE
- VE Database
    - Advantages
        - Cables/Harness schedule
        - We can use the same WO created by the stockroom
            - Parts traceability
            - Cables/Harness traceability
        - Different WO can be created if is preferred.
    - Disadvantage
        - Not user-friendly
        - Complex database
        - Schedule module cannot be used, WOT closing takes time and /or has never been closed.
        - Extensive training

CONCLUSION

The Database to be used in the harness shop has been selected. Meetings with the technicians have been completed.

The second phase of the project is the implementation of the database:

- Open a database account for all the personnel that needs to create, approve, and validate Work Orders.
- Paperless implementation by the end of July 2022.
- Training completion by June 2022.
- Create the test Work Order by June 2022 and run the test for process validation.
- Eliminate all the paperwork related to the Work Order Traveler.
- Work Order Closing as soon as the last step is completed.

Once the project is implemented, the expectations are to run the Harness Fabrication 90% paperless.

REFERENCES

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