Work-cell Centric Satellite

Pulse Flow Production System

Integration and Test

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Systems Engineering and Lean Approach

Typical Satellite Operational View
Jose L. Medina

• Employment:
  – The Boeing Co.
  – Division: Space & Intelligence Systems
  – 1998 - Present

• Work Experience:
  – 13 Years experience in Systems Test & Integration

• Education:
  – M.B.A. University of Redlands (2010)
  – M.S.S.E. Loyola Marymount University (In-process)
Agenda

- Introduction
- Systems Engineering and Lean Approach
- Design of Lean Pulse Factory
- Benefits
- Ethics
- Conclusion
- Questions
Introduction

• Attempt to change the way a company has been building satellites for the past 50 yrs.

• Specifically focus on the Integration and Test phases of the satellite processing.

• Eliminate the massive waste in the everyday activities.

• Organize the work per Work-cell rules and redefine the roles and responsibilities of team members.

• Implement the 2 major pillars of Lean Thinking
  – Continuous Improvement
  – Respect for People
Systems Engineering

• **SE is the Interdisciplinary Field of Engineering that focuses**
  - Design and management of complex engineering systems over the lifecycle

• **Initially SE emphasized technical performance and risk management of large complex systems, over time it has evolved into the following:**
  - Systems conceptual design
  - SE technical management
  - Tech analysis and evaluation
  - Product realization
  - SE Process control
  - SE Product Control
Lean Thinking

• Customer focused processes where all team members work continuously with a common goal
  – To eliminate waste and create value

• The Lean Approach has been captured into 6 Lean Principles.
Six Lean Principles

- **Specify Value:** Value is defined by the end user.
- **Identify the Value Stream:** Map all steps involved in the creation of value.
- **Value Flow:** Organize flow into predictable flow with no stoppages or backflow.
- **Pull Value:** Deliver value when needed, and pull value from upstream.
- **Pursue Perfection:** Make imperfections visible and apply continuous improvements.
- **Respect for People:** People are the most important resource; require mutual respect, trust, honesty, teamwork, leadership, and open communication. (Adopted from: [Oppenheim, 2011])
Lean Systems Engineering

- Over the years, SE has become burdened with inefficiencies, taking into a "bureaucracy of artifacts" rather than the engineering of great products.

- Recently SE and Lean thinking have been merged as Lean Systems Engineering for complex engineering projects in order to:
  - Add efficiency
  - Add value
  - Reduce waste
Two Major Pillars of Lean Thinking

• **Continuous Improvement**
  - In order to implement a production system based on Work-cell Pulse Flow I applied the 6 Lean principles, to organize this project and initiate continuous improvement.

• **Respect for People**
  - To clearly identify the roles and responsibilities of Work-cell team members, I applied a subset of Lean Enablers for Systems Engineering (LEFSE), (specifically Lean Principle 6)
Major elements of a commercial satellite
Bus Module

- Accounts for about 45% of the satellite

- Typically are similar up to about 85%

- Contains most Subsystems
  - Power (Batt/Solar)
  - Propulsion
  - Attitude Control
Bus Module
Bus Module Integration (BMI) & Bus Module Test (BMT)

- In order for Bus Module to be complete
  - Bus Module Integration
    - Structure
    - Harness
    - Bus Units (approx 20-30)
    - Propulsion (plumbing, valves, thrusters)
  - Bus Module Test
    - Initial power up
    - Verify connections
    - Units
Design of Lean Pulse Factory

Current State Of BMI & BMT

• Involves
  – Relocating the satellite multiple times
  – Relocating tooling
  – Relocating test equipment
  – Every program organized as a separate factory.
Design of Lean Pulse Factory

Current State

Set up Satellite Test Equipment Prop Harness Checkout

Perform Prop Checks Harness Valves Connectors Prop Lines

Move Bus Module To Structures

Finalize Bus Module Structure Install Inner/Outer Panels

Move Bus Module High Bay Lab Unit Install

Install Flight Units to Bus Module

Move Bus Module For LST Integration

Perform Powered Bus Module Test

Move Bus Module To Structures

Propulsion Install Prop Lines Valves Thrusters

Move Bus Module To Harness Lab

Install Harness Connectors Brackets Pan poles

Move Bus Module Structure To Propulsion Lab

Build Up Satellite Bus Module Structure

Move Bus Module Structure To Propulsion Lab

Structure Parts Panels Frame Struts

Satellite Current Flow
Bus Module Integration & Bus Module test
Current State Satellite Relocation
Minimum Manpower Requirements & People Positions

Floating Team
- Observer
- Person in charge

Satellite
- Air gauge controller
- Float controllers

Direction of travel
- Team member
  - Ground cable
  - Air hose controller

Ground
- Float controllers
- Observer
Design of Lean Pulse Factory

Future State

Pre-Integration and Test

- Units, Parts Sell-off
- Integration Readiness Review (IRR)
- Test Readiness Review (TRR)
- Parts kitting
- Planning

Production

**Work Center 1**
Bus Module Integration (BMI)
Bus Module Test (BMT)

- Integrate Bus Structure
- Install Propulsion Lines Valves
- Install Bus Harnesses
- Install Brackets EMI/RFI Shields
- Install Brackets EMI/RFI Shields
- Install 23 Bus Units
- Complete Harness Install Flight Mate Units
- Perform Unpowered BMT
- Perform Powered BMT

**Work Center 2**
Add Payload

- DOP-15 TRR
- IIST Mech IRR
- IIST Alignment/Dep.
- IIST Mech PTR
- Gate 12 & Environ TRR
- Acoustic/Post Acoustic Alignment/Dep
- SCTV Env. Preparation
- SCTV PTR & WC Sell-off

**Work Center 3**
Thermal Vac Test

- SCTV TRR
- SCTV End Bell Prep Pulse Position #7
- Ambient Test
- Hot/Cold/Cycle Test
- SCTV PTR
- WC Sell-off

**Work Center 4**
Final Int & Test

- FIST IRR/TRR
- FIST Align/PIM Prep
- FIST
- FIST PTR
- Flight Final SA Off Loader
- Flight Final Dynamic Balance
- Flight Final PTR
- Flight Final Containerization

Launch / Mission

- Gate 13
- Launch
- Mission

Satellite Flow Organized Around Work Centers
Design of Lean Pulse Factory

Work-cell 1 Set-up

• A radical change from the current to future state is that
  – Satellite will remain fixed within Work-cell 1 BMI/BMT tasks.
  – Team members will move in and out in sequence of required operations.
  – Satellite parts, tooling and equipment will be moved and staged in Work-cell1, as kits.
  – Once the Bus Module is integrated and tested, it will pulse in to the next Work-cell 2 (when created).
Design of Lean Pulse Factory
Future State

Work-center 1 Satellite Flow
Bus Module Integration & Bus Module Test

Kitting Equipment Tooling Work-cell 1
Integrate Bus Structure
Install Propulsion Lines Valves
Install Bus Harnesses
Install Brackets EMI/RFI Shields
Install 23 Bus Units
Complete Harness install Flight Mate Units
Perform Powered BMT
Pulse To Work-Cell 2

Eliminates 5 Satellite relocations and 3 STE Set-ups
Work-cell 1 Set-up

8 Tactics used to implement

1. Value Stream Mapping & Analysis
   - Defines Current - Future State

2. Balance the Line
   - A balanced satellite line is based on work distributed efficiently & appropriately

3. Standardized Work
   - Work Cell Standard processes and procedures established

4. Put Visuals in Place
   - Work-cells organized in a manner specific to visual control, Scoreboards and Pacemakers made visual

5. Point of Use Staging
   - Feeder Lines arranged to deliver to specific Pulse Position POU, Parts, materials, supplies, drawings, tools

6. Establish Feeder / Supply Lines
   - SV Prep & Stage subsystems such as, Propulsion, and Harness in Feeder Line configuration

7. Break-Through Process Re-Design Along Main Line
   - Conduct lean events to increase output capacity for flight parts, non-flight parts, tooling and Satellite Test Equipment.

8. Convert to Pulse Line (phases)
   - Implement plan to convert work-cells to a pulse line configuration
Design of Lean Pulse Factory

Work Cell Set-up

Work-cell 1 Layout

Parts & Tools
Kitting Area

Satellite
Test

Moving Work Benches

Satellite
Integration

The red arrows indicate parts/tools kits flow into the area, deployed within the work cell, and moved out after use.
Design of Lean Pulse Factory

Work Cell Set-up for BMT Tasks
Roles and Responsibilities

- The proposed Work-cell centric satellite production system requires a higher level of job description for employees.
  
  - **Work-center Leadership Team**
    - Program Office
  
  - **Functional Managers**
    - Direct managers of the different organizations involved
  
  - **Integration Managers**
    - Manage everyday tasks (manpower, kits..)
  
  - **Team Members**
    - People performing the work
Roles and Responsibilities

• Work-center Leadership Team (Program Office)
  
  - Their primary function is to set the vision, communicate direction.

  • Develop and maintain an aggressive business plan that supports the program's financial goals.

  • Providing the appropriate level of labor and material resources.

  • Set clear expectations, and communicate them across the teams.

  • Remove roadblocks that are inhibiting progress.

  • Develop and maintain strong relationships with the participating organizations and customer.
  • Recognize and celebrate program successes.
Roles and Responsibilities

• Functional Managers

  - Their primary function is understand the organization’s vision, goals, objectives, and develop a supporting strategy.

  • Facilitate the implementation of employee involvement teams.
  
  • Monitor and assist employee progress, by actively coaching and supporting skills.
  
  • Modify authority and control to match individual employee maturity.
  
  • Directly interface with team members and find opportunities to personally mentor them.
  
  • Be visible on all shifts and ensure good communication occurs at shift-handoff.
  
  • Monitor resource levels and hire to meet staff requirements.
Roles and Responsibilities

• Integration Managers

- Their primary function is to support daily activities by sharing accountability and cultivating an environment of continuous improvement.

  • Monitor attendance and assign resources to cover the work throughout the day.
  • Be visible on all shifts and ensure good communication occurs at shift-handoff.
  • Coordinate a daily plan with the team and provide it to the supervisor.
  • Ensure team has everything required to perform their work.
  • Understand parts, plans, tools, and processes of the area.
  • Exchange information and lessons learned with other team leaders.
Roles and Responsibilities

• **Team Members**
  - Their primary function is to work together to manage daily performance, achieve higher levels of quality, safety, and efficiency.

  • Follow documented standard work and best practices.
  
  • Utilize support resources (team leads) to correct problems throughout the day.
  
  • Work together to ensure all tasks are completed on time.
  
  • Ensure equipment and materials are returned to their appropriate location when not in use (5S).
  
  • Participate in setting goals for process improvement.
Benefits

- Great impact in reducing Manpower, Schedule, and Cost by:
  - Reducing number of unnecessary satellite relocations
  - Reducing the number of unnecessary satellite test equipment relocations
  - Reducing risk of damaged (handling) or lost flight hardware and equipment
## Benefits

Reduce number of Unnecessary Satellite Relocations

<table>
<thead>
<tr>
<th>Process Flow</th>
<th>Task Description</th>
<th>Heads</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite Lead</td>
<td>Generates Relocation Request</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Integration Lead</td>
<td>Reviews relocation request and puts plan resource plan together</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Mechanical Techs</td>
<td>Support Satellite relocation</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Quality Inspector</td>
<td>Ensures all move planning is in place and witness move</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Integration Lead</td>
<td>Closes relocation Request</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Total man hours required to perform tasks: **18**

Cost per move: **18 hrs * $225/hr Labor** = **$4050**
## Benefits

Reduce the Number of Unnecessary Satellite Test Equipment Relocations

<table>
<thead>
<tr>
<th>Process Flow</th>
<th>Task Description</th>
<th>Heads</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Requirements</td>
<td>Allocate the following resources for the BMT test phase: Standard PSTE (with LBCS), VSTR, LCM, LBTLs, STS server, two STS Client workstations, network switch, PSR.</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Requirements</td>
<td>Tag all equipment that needs to be moved.</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Certification</td>
<td>Submit the tickets request to have items moved over to the work cell.</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Requirements</td>
<td>Review layout provided by STEPM and Test Director.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Certification</td>
<td>Move SPE into workcell per STE layout.</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Certification</td>
<td>Gather all power and ground cables needed for the PSTE.</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Certification</td>
<td>Gather all interconnect cables for the PSTE.</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Certification</td>
<td>Connect power and ground cables to the PSTE, LBTLs, and VSTR.</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Certification</td>
<td>Connect the interconnect cables behind the PSTE.</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Certification</td>
<td>Power on all PSTE in the workcell and check status of the STE.</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Certification</td>
<td>Move workstations into place per layout.</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Certification</td>
<td>Power up workstations.</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

### BMT Bus PSTE/Workstation Configuration

| Certification | Configure PSTE     | 1 | 1 |
| Certification | Configure Workstations | 2 | 2 |

### BMT Bus PSTE Certification

| Certification | Run Auto Psim calibration or Manual Calibration on MPR. | 1 | 2 |
| Certification | Gather test cables per programs Power up SOP for the following modes: Battery Cell Simulation, Battery Cell Monitoring, UMB, MBP, SAS, LVB, BSP, BCS, and BEL. | 2 | 6 |
| Certification | Cable up for UMB polarity check per figure in the Power up SOP. Use the BEL cables if required. Run UMB Polarity check. | 2 | 2 |
| Certification | Cable up for MBP polarity check per figure in the Power up SOP. Use the BEL cables if required. Run MBP Polarity check. | 2 | 2 |
| Certification | Cable up for SAS polarity check per figure in the Power up SOP. Use the BEL cables if required. Run SAS Polarity check. | 2 | 3 |
| Certification | Cable up for LVB polarity check per figure in the Power up SOP. Use the BEL cables if required. Run LVB Polarity check. | 2 | 2 |
| Certification | Cable up for BSP polarity check per figure in the Power up SOP. Use the BEL cables if required. Run BSP Polarity check. | 2 | 2 |
| Certification | Cable up for BCS polarity check per figure in the Power up SOP. Use the BEL cables if required. Run BCS Polarity check. | 2 | 2 |
| Certification | Cable up for Battery Cell Simulation polarity check per figure in the Power up SOP. Run BCS mode Polarity check. | 2 | 2 |
| Certification | Cable up for Battery Cell Monitoring polarity check per figure in the Power up SOP. Run BCM mode Polarity check. | 2 | 2 |
| Certification | Certify the VSTR per procedure.                                                  | 1 | 4 |
| Certification | Update the bus set up request with all gathered data during all polarity checks. | 1 | 2 |

### BMT Bob cables and BTD Kit

| Certification | Gather all bob cables required plus the mating cable to perform CKT testing. | 1 | 16 |
| Certification | Run CKT testing on all bob cables required.                                      | 1 | 8 |
| Certification | Gather all connector savers, plugs, and DSLs for the BTD kit required for BMT testing as listed in the SSR. | 2 | 12 |
| Certification | CKT all DSL-1 and DSL-2.                                                         | 1 | 2 |

### BM AUX equipment

| Requirements | Review SSR and bus set up request for all AUX equipment needed for the BMT test phase. | 2 | 2 |
| Certification | CKT test cables, heater plates.                                                    | 1 | 1 |
| Certification | Check out the Valve test boxes per procedure.                                     | 1 | 1 |

**Total man hours required to perform tasks:**

- **2 Heads performing job:** 63.6 Hrs
- **2 Heads working 8 hrs/day:** 7,937.5 Days
- **176 hrs * $225 /hr Labor:** 28,575 $
Project Benefits

Work-cell 1 Cost Savings

• Satellite Relocations
  – Work-cell 1 will eliminate 5 unnecessary satellite relocations
    • $5 \times 4050.00 = 20,200.00$

• Satellite Test Equipment Relocations
  – Work-cell 1 will eliminate 3 unnecessary STE relocations
    • $3 \times 28575.00 = 85,725.00$

• Total savings
  – $105,925.00
Ethics

- Project involves a major redesign of factory operations therefore, will not be implemented “overnight”.

- Once Implemented
  - Improve work moral
  - Employees will feel sense of pride in their work
  - Overall positive workplace environment
  - Strengthen integrity of workforce
  - Improves ethics of corporate operations
  - Improves customer satisfaction
Conclusion

• This project will accomplish:
  
  – Clearly identifying roles and responsibilities
  
  – Implementing a work-cell centric production line
  
  – Implementing continuous improvement
  
  – Eliminating waste
Questions?