Ensuring Reliability in Lean New Product Development

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Overview

• Introduction and Definitions

• Part 1: Lean Product Development
  – Lean vs. Traditional Product Development
  – Key Elements of Lean NPD
    • Customer Defines Value
    • Front Loaded and Knowledge Based
    • Eliminate Redesign Waste
  – Reliability Requirements

• Part 2: Reliability Elements of Lean NPD
  – Lean FMEA and DRBFM
  – Critical Characteristics
  – DFR and Physics of Failure
  – Accelerated Testing to Failure
  – Failure Analysis and Knowledge Capture
Definitions

- **Robustness** – performance is less sensitive to sources of variability (Ability to perform in unexpectedly severe environments)
- **Reliability** – probability that product will perform intended function for specified duration under expected operating conditions
- **Durability** – product has acceptable useful life without significant deterioration
- **Quality** – product delivers specified performance new and each time it is used
Part 1:
Introduction to Lean New Product Development
Old Approach to Quality & Reliability

- **Traditional companies** (not yet on lean journey)
  - Make all design decisions affecting quality and reliability at the individual design engineer level
  - Pay little attention to historical failures
  - Assume that the ownership for quality and reliability belongs to groups named quality and reliability
  - Assume that **design does not significantly affect quality and reliability**, that quality and reliability failures are caused by manufacturing and suppliers
Typical Processes

• Staged Development with Gate Reviews
  – Used in Most Companies since 1980s, 1990s
  – Characterized by Rework Loops when ProblemsEncountered
    – Same as Competition
• Concept Selected Early
  – Developed Until Problems Discovered
  – Rework or Restart with New Concept
  – Continue Until Schedule or Budget Limit Reached
  – Results in Redesign Waste
• Milestone Based Process
Lean Approach to Quality & Reliability

• **Lean companies**
  – Prevent product failures rather than react to them
  – Create the culture to design quality and reliability into their products
  – Product development teams ensure that the quality and reliability issues of customers, manufacturing, service, and suppliers are properly represented
  – Open communication channels with customers to obtain timely and detailed product failure data
  – Maintain a well-conceived failure database of product field failure modes supported by failure analysis to root cause
  – Understand in detail the capabilities and limitations of both internal and suppliers' manufacturing operations
Lean NPD Benefits

• **Benefits of Lean**
  – Frees resources formerly spent fighting quality and reliability brushfires, permitting tasks to be performed faster and on-time
  – Reduces warranty costs
  – Makes it easier and cheaper for your manufacturing and your suppliers to produce quality products
  – Increases sales because reliable products make happy customers
  – Creates an atmosphere and culture of doing things right the first time
Lean Product Development Concepts

• **Customer Defines Value**
  – What is Customer Willing to Pay For?

• **Eliminate Waste**

• **Front Loaded Process:**
  – Clear Requirements and Understanding Customer Needs and Wants
  – Identify Knowledge Required to Satisfy Customer Requirements
  – Focus Resources on Key Tasks that Enable Essential Decisions and Fully Explore Alternatives

• **Knowledge Based – Learn & Understand**
### Traditional vs. Lean NPD

<table>
<thead>
<tr>
<th>Category</th>
<th>Traditional</th>
<th>Lean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Decisions</td>
<td>Made as Early as Possible</td>
<td>Delayed as Long as Possible</td>
</tr>
<tr>
<td>Design Iterations</td>
<td>Design is iterated until specification is met (or scheduled time reached)</td>
<td>Specifications Converge with Design</td>
</tr>
<tr>
<td>Prototyping and Testing</td>
<td>Verification to determine what needs to be fixed</td>
<td>Build knowledge to make decisions and achieve optimal designs</td>
</tr>
<tr>
<td>Project Management</td>
<td>Administrative – Few people create task based plans and track progress</td>
<td>Technical – Chief Engineer defines product concepts and milestones. Engineers create their own plans</td>
</tr>
<tr>
<td>Manufacturing Involvement</td>
<td>Manufacturing is follower and advisor – receives design</td>
<td>Customer drives and sets tolerances and key characteristics</td>
</tr>
</tbody>
</table>
To Change the Results, Change the Thinking

The traditional process:

- Define Requirements
- Design Solution
- Find out it doesn’t work

OUT OF TIME OR MONEY?

TRY AGAIN

YES

LIVE WITH IT

Learning-First Product Development

The cost of doing product development well is clear and obvious.
The cost of doing product development poorly is vague and distant.

If you want to change the results, you have to change the thinking
Focus on Learning to Accelerate the Process

**REACTION**
Time between the opportunity appearing and the decision to invest

**EXPLORATION**
Time during which multiple alternative implementations are explored

**LOCK-IN**
Time during which only a single solution is detailed

**FIX-UP**
Time during which we try to deal with the problems with the solution

(MINIMIZE) (MAXIMIZE) (MINIMIZE) (MINIMIZE)

**Project Lead Time**

*Only exploration efficiently adds knowledge. Lock-In and Fix-Up add knowledge only about the current solution. This doesn’t help future projects or do much about a bad initial concept.*

- The biggest source of waste in NPD projects is lack of knowledge when a decision must be made (results in *guessing*).
- Guessing usually results in rework that extends schedules.
- If you want to shorten project lead time, stop the guessing.
- To stop the guessing, increase the time spent *learning*.

*Out-learn the competition to shorten the development cycle.*
Lean NPD Characteristics

- Intense Focus on **Value Creation**
- **Standardized Work Processes**
- Develop **Information as Needed** (Pull)
- Parallel Processing – **Integration Events**
- Eliminate **Waste** and Unnecessary Handoffs
- **Up Front Learning** – Test First, Then Design
- Flexible Resource Loading & Timing
Cost Benefit Of Lean NPD

Learning from Failures

• Look at Lean NPD as a “Failure Mode Factory” *
  – Learn by finding and fixing the product and process failures before they reach the customer
• Lean NPD is a Knowledge Work Job Shop**
• Lean NPD is Conducive to Applying HALT, DOE, and Accelerated Test to Build Knowledge and Improve Design Decisions

* Dr. Nathan Soderborg, DFSS Master Black Belt, Ford – WCFB DFSS Conference, Feb 10 2008
Lean NPD Principles

- **Define Value** – Be Certain What the Customer Values (Understand the Real Need)
- **Identify Value Stream** – Tasks and Resources That Add Value at Right Time
- **Create Value Flow** – Get Rid of Wasted Activity, Do Only Tasks That Add Value
- **Establish Pull** – Deliverables Late as Possible with Maximum Knowledge
- **Seek Perfection** – Continuous Improvement and Learning
Lean NPD Support

- Top Management Support is Essential
  - Must be part of broader organizational lean journey
  - Probably an extension of previous lean manufacturing efforts

- Lean Consultants can Facilitate Transition to Lean NPD
Understand Customer Needs

• Voice of the Customer

• True Needs – Understand What Drives Them

• Develop Vision of Product with Customer
Kano Diagram – Customer Expectations

Use Voice of the Customer (VOC) Sessions to Identify
Customer Defines Value

• Product and Priorities Established with Customer:
  – What is Absolutely Essential?
  – Areas of Potential Compromise / Trade-off
  – True Need for Targets and Features
    • Opens Door for Possible Alternatives and a Better Solution to the Customer’s Problem
Agreement on Needs

• Based on the weighting, Kano and effort rating, sort the needs into four (4) categories:
  – What do we want to excel at?
    • This is the primary purpose of the project
    • If we do this and nothing else, the project will be a success
  – What would we like to improve if we can?
    • These are things the customer values
    • Can be sacrificed if the project gets in trouble (roll them into the next project)
  – What must not be compromised?
    • Mess these up and the project fails
  – What can be compromised?
    • Nothing comes for free
    • If we are going to excel at something, what is the trade-off to do that?
Quality Function Deployment

1. Objective

2. Customer Needs

3. Requirements Characterization and Verification (Weight and Kano Classification Typically)

3* = Requirements Characterization and Verification (Weight and Kano Classification Typically)

4. Competitive Analysis

5. Supplier "Responses"

6. Relationship Matrix

7. Interactions (Leverage and Conflict)

8. Targets and Gap Analysis

9. Importance

9 “Rooms”
Lean QFD Elements

Translating Requirements into Prioritized Targets

Customer Needs

Priority of Requirements

Knowledge Required To make Design Decisions

Features

1. “whats”

2. “hows”
Lean QFD Example

<table>
<thead>
<tr>
<th>Possible Functions that Could Deliver Desired Benefits</th>
<th>Key Customer Benefits</th>
<th>Weighting Factor</th>
<th>Customer Rankings of Functions</th>
<th>Function Priority No.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A) Mobile 24-Hr Comm</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B) Lightweight</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C) Large Service Area</td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Wireless Transmit Receive</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>17.5</td>
</tr>
<tr>
<td>2. Fits into Shirt Pocket</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>3. Audible/Silent &quot;Ring&quot;</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>4. Long Distance Reception</td>
<td>4</td>
<td>0</td>
<td>5</td>
<td>15.5</td>
</tr>
<tr>
<td>5. Usable at Night</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>6. Voice and Data Capability</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>7. Color Display</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>8. Games</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9. Text Messaging</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>/</td>
</tr>
<tr>
<td>10. Digital Camera</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Notes:

a. Try to keep benefits to a small number so you can focus on the critical few
b. Key Benefits are Weighted 1 to 3 in .5 increments
c. Functions are scored from -5 to +5 in whole numbers
Critical Characteristics and Parameters

Key Characteristics are "product features, manufacturing processes, and assembly characteristics that significantly affect a product's performance, function, fit, and form".
Critical Characteristics
Management

• Increase Margin
• Reduce Variation
• Design of Experiments
• Lean NPD Focuses on Critical Few Parameters
Key Characteristics Development

Customer Requirements
- planning
- change control
- system design
- customer-designated, AND
- supplier-designated
- parameter design (target)
- tolerance design

Product Design Requirements
- manufacturing feasibility
- system design

Tools include:
- QFD
- APQP
- FMEA
- Statistical Engineering

Product Characteristics
- customer-designated, AND
- supplier-designated
- parameter design (target)

Process Design Requirements

Process Characteristics
Lean QFD and FMEA

Lean QFD
- Unknowns
- User Environment
- Key Characteristics (CTQ)
- Potential Tradeoffs

Lean FMEA
- Risks Due to Changes
- Operating Stresses, Unknowns
- Key Characteristics (CTQ)

Integrate Risks & Learning Needs in Project Decision Flow

Value Stream For Task Execution
Value in NPD Through Risk Reduction

Activities increase knowledge, reduce risks and unknowns, apply and use resources, thereby adding value.

- Risk and Unknowns
- Knowledge Gained and Issues Resolved
Decision Making Process

• Use Lean QFD Matrix to Identify:
  – Decisions Required to Develop Required Features
  – Knowledge Needed to Make Decisions
  – Timing Required for Decisions

• Determine How Missing Knowledge will be Acquired Through Analysis and Testing

• Integration Events Where Knowledge is Required to Make Decisions
Decision Flow Matrix

Identify Decisions Needed to Make Product

Identify Unknowns

Decision Sequence with More Difficult Earlier

Learning First

Integration Points to Make Decisions

Post-Its® On Board in Team Room

Team Members

Responsibility for Decision

Timing

Learning Required

Decision & Integration Points

Output
Value Stream Analysis (VSA)

- Work the project as a rolling sequence of tasks
- Tasks change almost daily as new things are learned
- Tasks are pulled by the person doing the work
  - Not assigned by a project manager
  - Person writes what they will do
  - Team agrees on what is written and who is involved
- Tasks are pulled only at the rate that makes sense
  - Not more than a couple months
  - Maybe only a week or two
  - Depends on the pace of learning/change

VSA makes project planning a team based activity
Lean NPD Value Stream Mapping

- Start with Current PD Process State
- Identify Wastes
- Future State Based on Pull of Information When Needed and Removing Tasks that Do Not Add Value
- Several Tools Available to do PDVSM
Vertical Value Stream

- Use Post-Its® for Tasks & Resource Assignments
- Rolling Window of Tasks / Assignments for Week or Month
- Team Room Chart
- Project Planning & Management is a Team Activity
- Stand Up Daily or Weekly Status Meetings
- Provides visual status for project management

![Diagram showing team members and tasks]
Design Structure Matrix (DSM)

DSM is one of Several Tools for Value Stream Mapping of the PD Process

- **Flow**
- **Resources**
Set Based Design

• Development of Multiple Early Designs
• Capture of Reusable Knowledge
• Multiple Concepts Developed in Parallel
  – Enables Transition to Alternate Design if Preferred Concept Cannot Meet Requirements
• Focus is on Getting it Right Up Front
• Greater Investment Earlier, More Savings in Development and Production
Set-Based Design is not Point Based Design
Comparison

Set-Based Concurrent Engineering

"Point-Based" Concurrent Engineering

Iterate if Required

Few Concepts  Select  Detail  Test

"Set-Based" Concurrent Engineering

Many concepts for each system

- Evaluate against trade-off curves
- Eliminate the weak
- Add knowledge
- Combine in different ways
Convergence in Set Based Design

Explore solution space, Find Intersections, and Converge on a Solution

Subsystem A Capability

Component B Alternatives

Styling Alternatives

OK
Set Based Concurrent Engineering

Challenges in Set-Based Design

• Developing Multiple Solutions in Parallel for a Longer Time – Cost & Resources
• Analysis and Test on Multiple Versions
• Decisions Deferred Until Alternatives are Understood in More Detail
Opportunities in Set-Based Design

• Select Most Robust and Reliable Concept
• Comparison Analysis and Test of Alternatives
  – Design of Experiments
  – HALT and Accelerated Stress Test
  – Stress Analysis
Change Point Analysis

• Understand Risks Qualitatively
  – What has Changed? Why? Prioritize Actions
  – New Design or Technology
  – Supplier – New, Alternate, Process Change
  – Environment: New Stresses, New Operating Envelope, Standards Changes
  – Customer: Application Change, Expectations Raised, Competition has Changed, Market Changes
  – Consequences of Failure Changed: Warranties, Regulatory Compliance

• Impact on Product and Design, Focus Resources on Changes Needed
Focus on New Features and Modifications

• Modular Design, Standard Platforms and Part Reuse Emphasize Proven Components – Understand Baseline

• Most Risk is in Developing New Features:
  – New Operating Environment
  – New Applications of Existing Technology
  – Development of New Technologies or Processes
  – Supplier Changes – Source or Process
Customer Needs
• Multiplicity of Features
• Lower Cost
• Fast Delivery
• High Quality

Present Design & Production Process
• Produces Unnecessary Variation (Numerous Part Numbers & Processes)
• Variation Increasing Every Year

Improveement Strategy
(Minimize the Unnecessary Variation)
• Modular Design & Production - Selection and Reuse of Preferred Parts, Subassemblies (Modules) & Products
• Meet Common Customer Requests with Minimum Product Configurations, Part Numbers and Processes

Benefits
• Reduced Overhead Costs
• Faster Delivery Times
• Reduced Direct Costs (Design, Material & Production)
• Improved Quality

Modular Products are Able to Meet Common Customer Requirements with Minimum Product and Process Variation
Modular Products, Platforms, Reuse
Mass Customization
Modular Products, Platforms, Reuse
Mass Customization

• Use of Proven Modules and Platform Products
  – Focus Reliability Efforts on Risks:
    • Interfaces with Subsystems & Other Components
    • Changes to Customize Design
    • Stresses from New Application
  – Build on Baseline Knowledge of Standard Platform and Modules
Reliability Program Elements
Applied to Lean NPD
Reliability Assurance

Front Loaded Lean NPD Tasks:

- Customer Requirements Design Goals
- Operating Environment, System Relationships, Interfaces
- FMEA, Robust Design DFX, FEA, Trade-offs
- Test, Failure Analysis, DOE, Compare Concepts
- Integration Point, Product Risk Decision
- Verification Testing, Requirements Met? Capture Failures and Learning

- Establish Reliability Goals
- Develop System Model
- Design for Reliability
- Conduct Reliability Development Testing
- Conduct Reliability Acceptance Testing

- Goals Met?
- RQMTS Met?

- Product Launch
  - YES: Monitor Operational Performance
  - NO: Maintain Design Reliability in Production

- Identify Variability in Processes, Implement Production Reliability Testing, Screening (HASS, ESS, ORT), SPC
- Warranty Data Collection, Improve Current & Future Product, Feedback in FRACAS, Baseline Knowledge


Begin Producing Product, Deliver to Customer
Reliability Requirements

• Customer Requirements
  – **Explicit**: Customer specifies quantitative measure (% reliability / time, MTTF, MTBF, minimum life etc.)
  – **Implicit**: Characteristics that necessitate level of reliability to meet (warranty, life-cycle cost, repair time)
  – **Not Expressed**: Supplier must uncover or anticipate (use surveys, VOC, QFD, benchmark)

• Operating Environment and Requirements
  – Internal or Industry Imposed Standards

• Reliability Goals & Objectives to position product for competitive advantage

• Products need to meet or exceed requirements to succeed in the market
Understanding Reliability Requirements

Requirement: 90% Reliability for 100,000 cycles with 50% confidence for a 99.8th percentile customer.

- The entire statement means:
  - The product must achieve 90% Reliability with 50% confidence at 100,000 cycles of use (or equivalent hours of damage).
    - This is based on testing at a stress level equivalent to a 99.8th percentile user (for a specific stress distribution).
Normal vs. Severe Use

Essential to Consider Severe User Stresses on Product
Reliability / Robustness in Lean NPD

- Capture & understand customer reliability requirements – Agree on Priorities
- Define specific tasks to accomplish reliability goals in decision flow and value stream analysis
- Integrate tasks and processes to meet reliability and robustness requirements
- Focus on building knowledge to reduce risk
- MUST BE PROACTIVE
Reliability / Robustness Plan

- Requirements Allocation / Apportionment
- Design or Process Changes from Baseline Designs
- Analysis, modeling, estimation methods
- De-rating criteria and product limits
- FMEA or DRBFM (Design Review Based on Failure Modes)
- Reliability Test Planning & Completion
  - Design of Experiments to Select Robust Alternatives
  - Accelerated Life Test (Qualitative & Quantitative)
  - Reliability Growth
  - Qualification Testing
  - Stress Screening
  - Production Reliability Test (PRAT/ORT)
- Design for Reliability and Robustness
- Part and Supplier Involvement / Qualification
- Failure Reporting, Analysis, & Corrective Action System (FRACAS)
Lean NPD Summary

• **Knowledge Based – Learning Unknowns**
  – Build on Knowledge Base
  – Concentrate on Changes and Unknowns

• **Focused on Value Customer Pays For**
  – Understanding Requirements

• **Eliminate Waste**
  – Fewer Reviews, Key Integration Points
  – Keeps Team Members Focused on Critical Tasks

• **More Up Front Work to Make Better Decisions and Eliminate Rework and Redesign**

• **Team Rooms with Visual Status Replace Review Meetings**