Statistical Engineering, Quality, and Competitiveness

Geoff Vining
Virginia Tech

Outline

- Deming: Quality, Productivity, and Competitive Position
- Innovation
- Influence of Lean Six Sigma
- Statistical Engineering
- Scientific Method
- Statistical Engineering Example
- Silos
- The Future

Deming

- Credited with Starting the Japanese Quality Revolution
- Student of Walter Shewhart Early in Career
- Deming’s True Statistical Area: Sampling
  - USDA
  - Census Bureau
  - Wiley Text – Late 1940s
  - Fellow of the American Statistical Association

Deming

- “Quality, Productivity, and Competitive Position”
- “Out of the Crisis” (Second Edition)
- Major Contribution: Management Philosophy
  - 14 Points
  - Good Quality Does Not Cost Money; It Saves
  - Better Quality Leads to Better Productivity
  - Better Quality Improves Competitive Position
- Deming’s Basic Tool: Shewhart Control Chart

Deming

- Strong Proponent of the Proper Use of Statistics
- Proper Application of Statistics is Essential to Good Quality
- Elevated the Role of Quality and Industrial Statistics/Quality Engineering in Companies
- Sets the Stage for Lean Six Sigma

Innovation

- Not Long Ago, Building Better Quality Was Significant Innovation
- High Quality Now Viewed as Expectation
- New Issue: Next Way to “Delight” Customers
  - “Improved” Current Products
  - New Products Customers Never Imagined

Innovation

- Types of Innovation
  - Disruptive: Paradigm shifts
    - Apple
    - Products that people want but do not know they want
  - Incremental: “Small” innovations
- Quality Engineering Techniques Support Both

Innovation

- Key to Innovation:
  - No fear of failure
  - Rapid Evaluation of ideas/prototypes.
- Keys to Success
  - Strong Interdisciplinary Teams
  - Support Creativity
  - Willingness to Experiment
  - Understanding: Early Failure Leads to Success
  - Sequential Learning

Lean Six Sigma - Components

- Organizational psychology, especially change management
- Large arsenal of analytical tools
    - Seven basic tools
    - Historic tools of industrial statistics
    - Heavy emphasis on software for analysis
- Project management – essential for a timely solution
- Structured problem solving - DMAIC

Lessons Learned

- Subject matter experts:
    - Important to train in simple tools, both “soft” and “hard”
    - Equally important: understand the limitations of that training
    - Need to know when to bring a statistical tool expert into the process
- Important role for quality engineers as integral part of problem solving teams
- Need for true collaboration

Contributions of Lean Six Sigma

- Emphasis on larger, meaningful to bottom-line results
- New metric – Dollar savings
- Six Sigma emphasized the need for top leadership involvement and commitment

Statistical Engineering

- Nature of quality engineering is changing!
  - No longer can we be simply analysts
  - Too easy to ship analysis over seas
- Survival as a profession depends on being able to add value
- The future: Being able to solve **large, unstructured, complex problems.**

Statistical Engineering

- Solutions require collaboration among high profile interdisciplinary teams!
- Problems cut across the organization
- Building upon Six Sigma
  - Good strategic structure
  - Need for something tactical in between
  - How do we deploy our tools?
- Success requires new tools and mindset

Statistical Engineering

- How we can generalize solution tactics to solve future problems?
- One pathway: Statistical Engineering
- Goal: Develop appropriate theory
  - to apply known statistical principles and tools
  - to solve high impact problems
  - for the benefit of humanity.
- Minimize “one-off” solutions

Statistical Engineering

- The heart of Statistical Engineering is the scientific method.
- Most theories underlying statistical engineering involve strategic application of the scientific method.
  - Deming-Shewhart PDCA (Plan, Do, Check, Act)
  - DMAIC (Define, Measure, Analyze, Improve, Control)

Scientific Method

- Inductive/deductive problem solving process
  - Understand the real problem at hand
  - Define the problem
  - Discover solutions
    - Abstract from the concrete to the abstract
    - Develop a theory
    - Test the theory using data
    - Modify the theory as necessary
- Need for Interdisciplinary Collaboration!

Scientific Method

- Data are the keys to the successful application of the scientific method
  - Data collection
  - Data analysis
  - Data Interpretation
- Quality Engineering/Industrial Statistics are the handmaiden.
- Very important role in solving large, unstructured, complex problems.

NASA Example - COPVs

- Small Statistical Engineering Project
- Overarching Question of Interest: Reliability of COPVs at Use Conditions for Expected Life of Mission
- Issues:
  - Many different types of COPVs used in spacecraft
  - Vessel tests are very expensive: money and time
- NASA Engineering Safety Center (NESC) Project

COPVs

- The Core NESC Analytics Team:
  - Reliability Engineers:
    - JPL
    - Langley Research Center
    - Glenn Research Center
  - Statisticians:
    - Marshall Space Flight Center
    - Virginia Tech

COPVs

- NASA Team's Approach: Focus on Strands Used to Wrap Vessels
  - Less expensive
  - Can have many more experimental units than for vessels
- Still Issue with Time to Test
- Problem: How Do Strands Predict Vessel Behavior?

COPVs

- Initial Study: Previous Strand and Vessel Tests
  - Relevant strand study conducted at a national lab:
    - 57 strands at high loads for 10 years
    - Net information learned: Strands either fail very early or last more than 10 years
  - Vessel studies:
    - Also 10 years
    - Weibull model parameters seem similar to strand studies

COPVs

- Team’s Initial Concept
  - Much larger study
  - Censor very early
    - Reduces time
    - Allows the larger study in a practical amount of time
  - Proceed in phases
  - Have detailed data records to track any problems

COPVs

- Phase A: Conducted During Shake-Out of Equipment
  - Small study (although bigger than the national lab study!)
  - Statistical goal: Determine if the parameters from the national lab study are valid as the basis for planning the larger study!
  - Note: Phase A gave the team an opportunity to re-plan the larger experiment, if necessary!

COPVs

- Phase B: “Gold Standard” Experiment
  - Planned time required: 1 year
  - Used 4 “blocks” of equal numbers of strands
    - Allowed the team to correct for time effects
    - Allowed the team to mitigate problems, especially early
  - Study assumed the “classic” Weibull model
  - Size of the experiment assured ability to assess model

COPVs

- Total Size of the Database: Huge
  - Kept data from start of specific strand test to failure on the second
  - Kept the last 2 minutes at the .01 second from buffer
  - Buffer allowed team to investigate unusual phenomena at failure
  - Essential for proper data cleansing

COPVs

- Parallel Vessel Study
    - Reasonably large ISS study targeted to end early (< 10 yrs)
    - Opportunity to step up loads to mimic strands
    - Censored but longer censor time than strands

COPVs

- Results to Date:
  - Phase A: Surprisingly similar to national lab study
  - Phase B:
    - Serious problem occurred with the gripping in the first block
    - Serious conversations with possibility of replacing!
    - Other three blocks well behaved and by themselves produced better than the planned precision for the estimates
    - Residual analysis confirmed the Weibull model

Why is COPVs Statistical Engineering?

- Application of Scientific Method to a Complex Problem
- Sequential Data Collection/Experimentation
- Each Phase Targeted Different Questions
- Clearly Documented Assumptions, Assessed via Data
- Took Proper Steps to Cleanse Data
- Real Research Question Involves System of Systems

Silos

- “Silos” are the major impediment to success!
  - Silos within Disciplines
    - Engineers only speaking with other engineers
    - Statisticians speaking only with other statisticians
  - Silos within Industries
    - Automotive people speaking only with automotive people
    - Aerospace people speaking only with aerospace people.

Silos

- Too many of us live only in our silo!
- Large, unstructured, complex problems require
  - New approaches
  - New insights
  - Cross-fertilization across disciplines and industries
- Example: Applying quality engineering tools/methods to finance, risk management, healthcare!

How Do We Tear Down the Silos?

- Recognize the problem!
- Understand that interdisciplinary teams are the future
  - Created for a specific problem
  - Each person’s subject matter expertise is essential
  - Learning how to apply solutions from other problems to address the problem at hand.
  - No more: My only tool is a hammer; so, …

How Do We Tear Down the Silos?

- Boundaries between disciplines must become more amorphous/less rigid.
- Important to stretch the overlap across disciplines.
  - Learn new “languages”
  - Learn new approaches to problems
  - Learn not to re-invent the wheel
- We need to create more opportunities to interact across disciplines.

Conclusions

- All Engineering Professions Must Realize:
  - Age of Innovation
  - Not a Fad
  - Adapt or Die
- Innovation Requires:
  - Interdisciplinary Teams
  - Ability to Experiment
  - Recognize that Failure Leads to Learning

Conclusions

- Success requires:
  - Interdisciplinary teams
  - True collaboration across all disciplines
  - Strong data analytic capabilities
  - Appreciation of Scientific Method
  - Ability to Solve Large, Unstructured, Complex Problems
  - No Fear of Failure!
- Statistical Engineering Has an Important Role!