

Solving Complex Problems: The Role of DOE and Analytics

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Outline

- Missing Link in Quality Improvement
- Scientific Method
- What is Statistical Engineering?
- Review Paradigm for Statistical Engineering: Chemical Engineering
- Understanding Big Picture of Statistical Engineering
- NASA Example
- Final Comments

“Missing Link”

- Many Problem Solving – Quality Improvement Strategies
 - Deming
 - CPI
 - TQM
 - Six Sigma
 - Lean Six Sigma
- Flavor of the Month

“Missing Link”

- Lessons Learned from the Past
 - Interdisciplinary Teams
 - Statistical Tools
 - Organizational Psychology – Team Dynamics
 - Project Management Skills
 - Strong Leadership
 - Senior Leaders
 - Team Leaders
 - Technical Leaders

Scientific Method

- Sequential Learning Strategy!
 - 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
- Strong Need for Interdisciplinary Collaboration

Scientific Method

- Data Are the Keys to Successful Application
 - Data collection
 - Data analysis
 - Data Interpretation
- Quality Engineering/Industrial Statistics Are “Handmaiden”
- Very Important in Solving Complex Problems.

Systems Approach

- A Start: Statistical Thinking
 - All Work Occurs within a Process
 - Note: Systems Thinking
- Missing Element: Systems Approach to the Solution!
- Solution Strategies Must Use a Systems Approach

What Is Statistical Engineering?

- Statistical Engineering: Solving Complex Problems with Data
- Complex Problems
 - Unstructured – Mess!
 - Usually Large
- Secrets to Success:
 - **Subject Matter Expertise for the Specific Problem!**
 - Tool Sets
 - Strategic and Tactical Deployment
- Paradigm: Chemical Engineering

Typical Steps in a Chemical Process

- Receipt of Raw Materials
- Initial Processing of the Raw Materials
 - Size reduction for solids
 - Purification (separation processes)
- Chemically Reacting the Raw Materials
- Purification of Final Product
- Packaging of Final Product
- Proper Preparation and Disposal of Waste Products

Unit Operations in Chemical Engineering

- Separation Processes
 - Solid-Liquid
 - Liquid-Liquid
 - Solid-Gas (Vapor)
 - Liquid-Gas
- Chemical Reaction Processes
- Solid Size Reduction
- Fluid Flow
- Heat Transfer

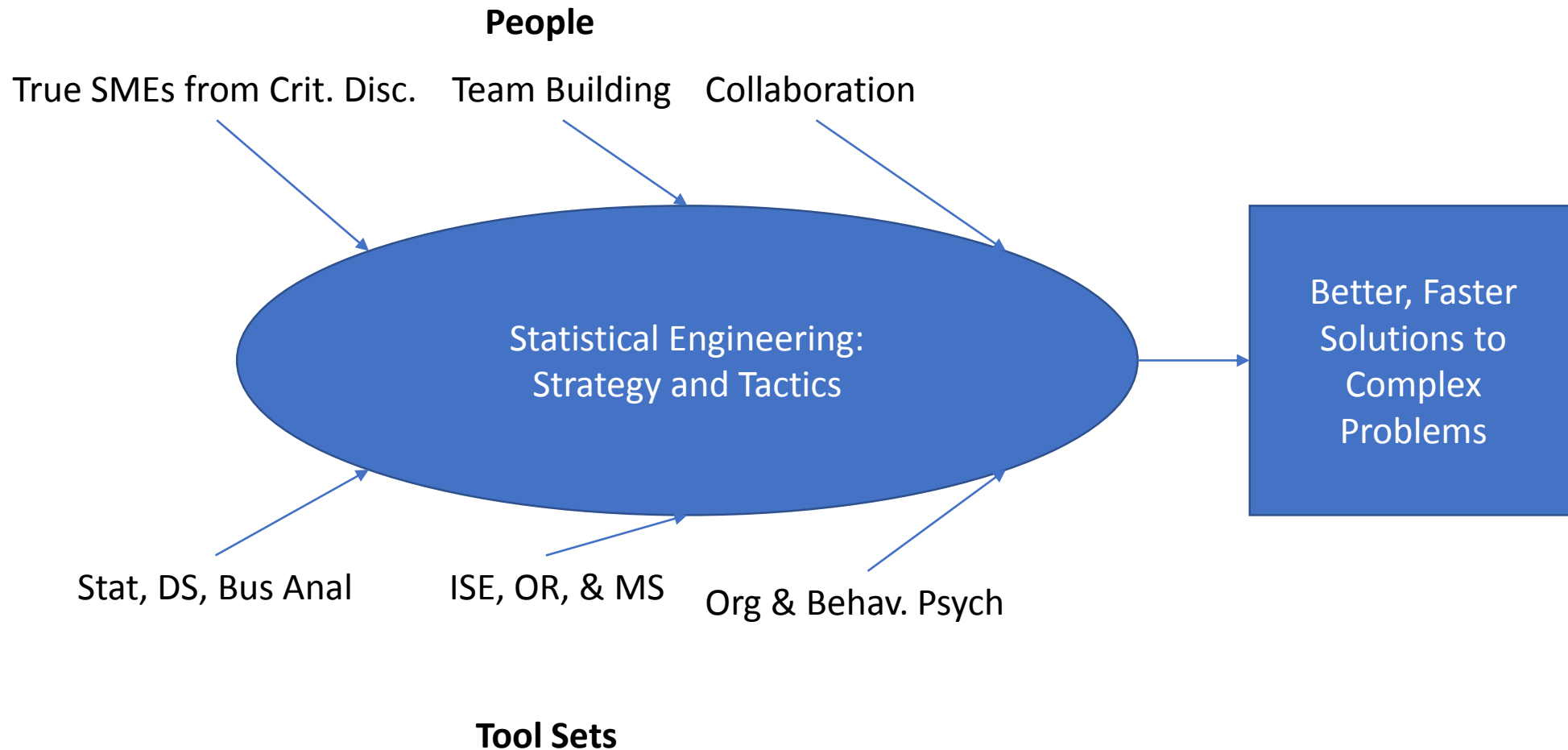
Overarching “Competencies’ In Chem. E.

- Basic Mathematics and Statistics, including Optimization
- Physical and Chemical Data
- Engineering Process Control
- Materials of Construction
- Engineering Economics

Spectrum of Projects in Chemical Engineering

- Designing a New Single Distillation Column
- Designing/Managing a Critical Chemical Sub-Process (Chem. Reactor)
- Managing a Small Group of Distillation Columns (Jack Daniels!)
- Designing and Managing a Complex Chemical Plant (e.g. TiO_2)
- Technical Support for a Domestic Product Line (Phosphates)
- Technical Support for a Global Inter-Related Product Portfolio (Nylon)

Schematic Diagram of Statistical Engineering



General Comments on Data Science

- Different Things to Different People
- Spectrum: Pure Computer Science to Statistics for Big Data
- Common Themes:
 - Coding
 - Database Processing/Management
 - Algorithms
 - Prediction, not Inference
- Approach Is Extremely Valuable if Properly Used

How Do Statistics/Data Science Fit in SE?

- Chemical Engineering – Unit Operations
- Statistical Engineering – Core Processes
- Both Are Sets of Tools Used as Building Blocks to Solutions
- Statistics and Data Science Are Broad Examples of Core Processes
- They Are Component Parts in a Much Larger Scheme, Stat. Eng.!
- Statistical Engineering:
 - Develop Efficient/Effective Strategy and Tactics to Solve Complex Problems
 - “Right Tool, for the Right Job, and the Right Time, Properly Applied”

Statistical Engineering Core Processes

- Data Acquisition – Applied Statistics (AS), Data Science (DS), Eng.
- Data Exploration – AS, DS
- Modeling
 - Traditional Statistical Methodologies – AS
 - Modern Analytics (Big Data Predictive Modeling) – DS
- Inference to the Process/Problem - AS
- Evaluation and Trial Deployment of Tentative Solutions – AS, DS, Eng.
- Deployment of Final, Sustainable Solution – Mostly Eng., Some AS, DS

Statistical Engineering Strategy and Tactics

(1) Identify Problem

(2) Provide Structure

(3) Understand Context

- Science
- Business
- Personnel
- Politics

Statistical Engineering Strategy and Tactics

(4) Develop the Specific Solution Strategy

(5) Develop and Execute Tactics to Achieve Solution Strategy

Iterate (4) and (5) as Necessary

(6) Deploy Final Solution, Summarize Learning

(a) Document the Process as a Case Study

(b) “Publish” the Final Document

Spectrum of Statistical Engineering Projects

- Planning/Analysis of an Experiment (Reflects Standards of Practice)
- Six Sigma Project (Reasonably Well-Defined Problem, 3-6 Months)
- Series of Focused Six Sigma Projects (Well-Defined, 12-18 Months)
- NASA Ares Rocket Project (Somewhat Defined, 5-8 Years)
- NASA Space Launch System (Not Well-Defined, 10-15 Years)
- US DoD F-35 JSF (Definition Changing over Time, 20-25 Years)

Examples from NASA: Ares - Constellation

- Intended to Replace the Space Shuttle
 - Everything Was “On the Table”
 - Complex Unstructured Problem!
- First Major Question: How to Replace?
 - Focus on Re-Purposing Shuttle Technology
 - Use Single Solid Rocket Booster plus Liquid Rocket Second Stage
 - Crew Capsule on Top of the Rocket
- Second Major Question: How to Adapt Prior Technology
- Note: Statistical Engineering Involved, Pre-Data!

Examples from NASA: Ares – Constellation

- Single Solid Rocket Booster
 - Data: Single Shuttle Booster Did Not Provide Sufficient Thrust (Eng. Decision)
 - Response: Shuttle Booster – 4 Sections; Ares – 5 Sections (Eng. Decision)
 - “Roll” Was Not an Issue with Shuttle Configuration
 - No Data on Roll for a Single Shuttle Solid Rocket Booster
 - Decision Must Collect Data on Roll
 - Need New Crew Capsule – Constellation (Many Subprojects)
 - Escape Systems for Astronauts in a Launch Abort (Have Some Knowledge)
- Statistical Engineering, Pre-Data Phases!
- Statisticians Involved even in These Steps!

Ares Rocket – New Booster Configuration

- Static Test to Determine Performance – SE Subproject (Pete Parker)
 - Standard Characterization – Thrust, Most Important
 - New Characterization – Roll
- Needed New Calibration System (All 6-12 Month Projects)
 - Subproject 1: Review Previous Calibrations for Static Test (DS/AS)
 - Subproject 2: Develop Appropriate Test Procedure for New Test (DOE)
 - Subproject 3: Conduct and Analyze Test on Standard Shuttle Booster (DOE)
 - Subproject 4: Conduct and Analyze Test on Prototype Ares Rocket (DOE/DS)
 - Subproject 5: Test Launch of the Ares Rocket (Confirm Solution)
- All Projects Involve Statistical Engineering (More than Six Sigma!)

Constellation

- Basic Design: Apollo Command Capsule
- Extensive Testing (All Statistical Engineering Projects)
- One Major Project – Escape Rocket System
 - Shuttle Had No Escape System – No Hope for Astronauts in Catastrophe
 - Apollo Did Have an Escape Rocket System – Starting Point
- First Step: Review All Data on Rocket Explosions on, near Pad (DS)
- Review Data to Determine Requirements for Crew Survival (DS/AS)
- Design Escape System to Meet Requirements (Engineering)
- Test System (Confirm Solution) (DOE)

Whatever Happened to Ares – Constellation?

- Obama Administration Canceled Project
 - Cost Overruns
 - Schedule Delays
- NASA Rarely Truly Cancels Projects!
- Ares – Space Launch System (SLS)
- Constellation – Orion (Capsule System, Human Deep Space Exploration)

Enduring Value of Statistical Engineering

- Success Requires Providing Value to Organizations
- Solving Complex Problems Provides Great Value
- Current State: Focus on Limited Number of Tools
- Future State: How Do We Use the Tools Most Effectively
 - Most Understand the Full Range of Tools Required
 - Most Understand Best Practices for Using the Tools
 - Must Understand How to Deploy the Tools Strategically
 - Must Understand Leadership in the Broad Sense
- The Future Is a Journey – ISEA (isea-change.org)!