Using the Power of Statistical Thinking

Stat-Ease 2nd Annual DOE Conference
Dinner Presentation
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Objectives

- Obtain a common understanding of Statistical Thinking, its definition, and its application
- Clarify the distinction between Statistical Thinking and statistical methods
- Demonstrate the power of Statistical Thinking in concert with DOE planning and analysis.

What is Statistical Thinking?

Definition

Statistical Thinking is a philosophy of learning and action based on the following fundamental principles:

- **All work occurs in a system of interconnected processes,**
- **Variation exists in all processes, and**
- **Understanding and reducing variation are keys to success.**

Glossary of Statistical Terms - Quality Press, 1996

Systems and Processes

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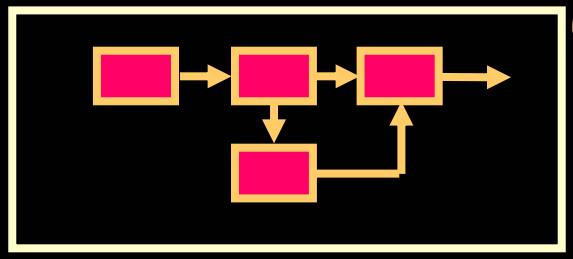
Process

A series of activities that converts inputs into outputs

Suppliers

Inputs

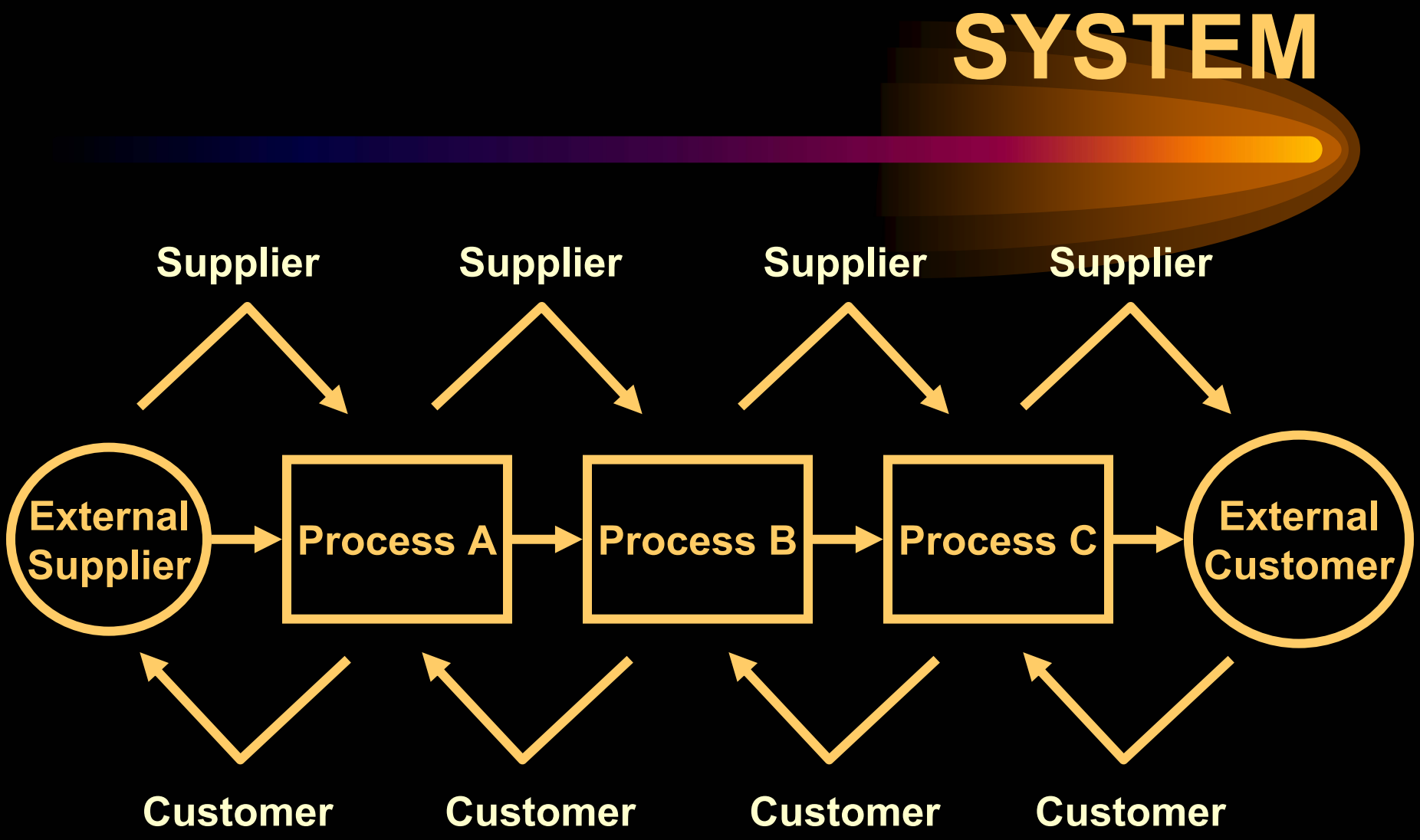
Process



Outputs

Customers

S I P O C


SYSTEM
Supplier
Supplier
Supplier
Supplier
External Supplier
Process A
Process B
Process C
External Customer
Customer
Customer
Customer
Customer

Process-orientation

Without a process context, practitioners often apply inappropriate statistical methods (such as performing ANOVA on unstable processes), which at best minimize their impact on improvement, and at worst, lead to mistrust of statistics.

Variation

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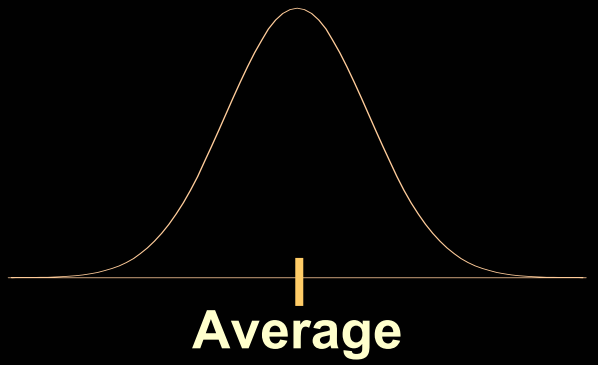
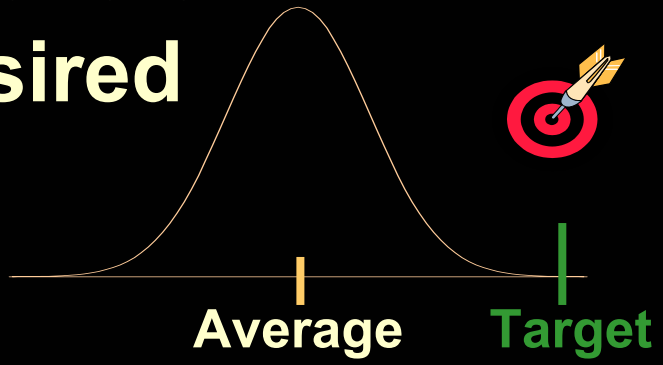
Variation and Targets

Variation can be thought of as:

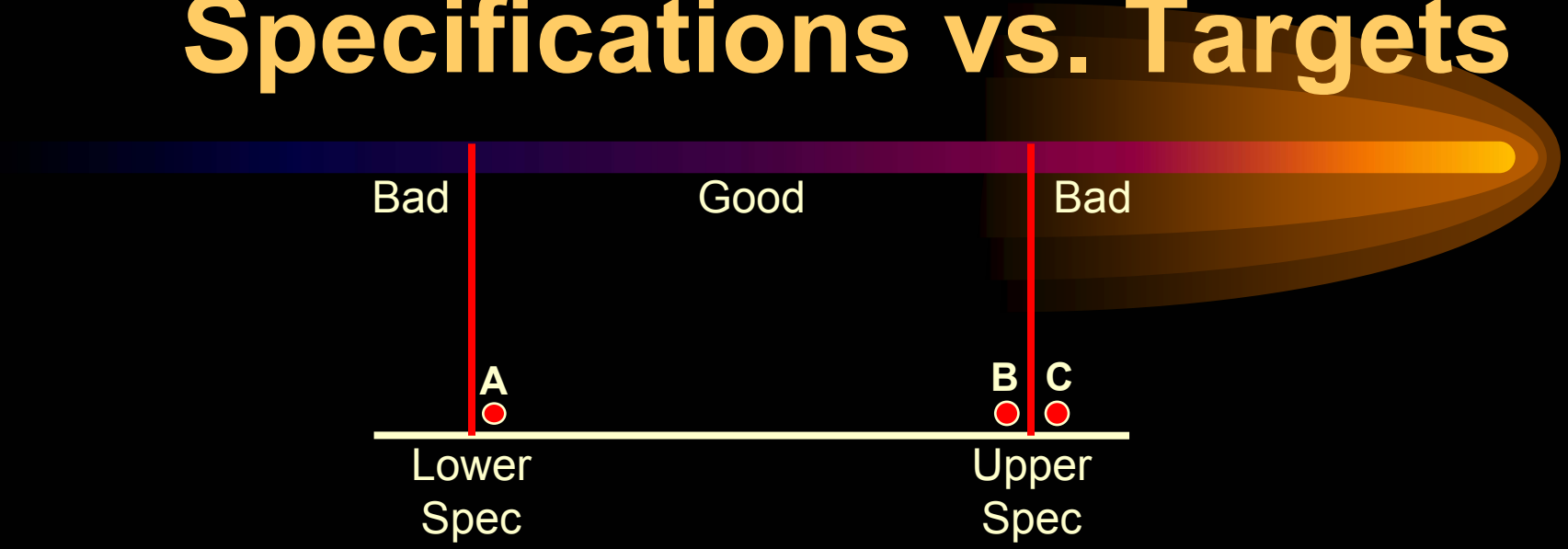
1. Deviations around the overall average, or

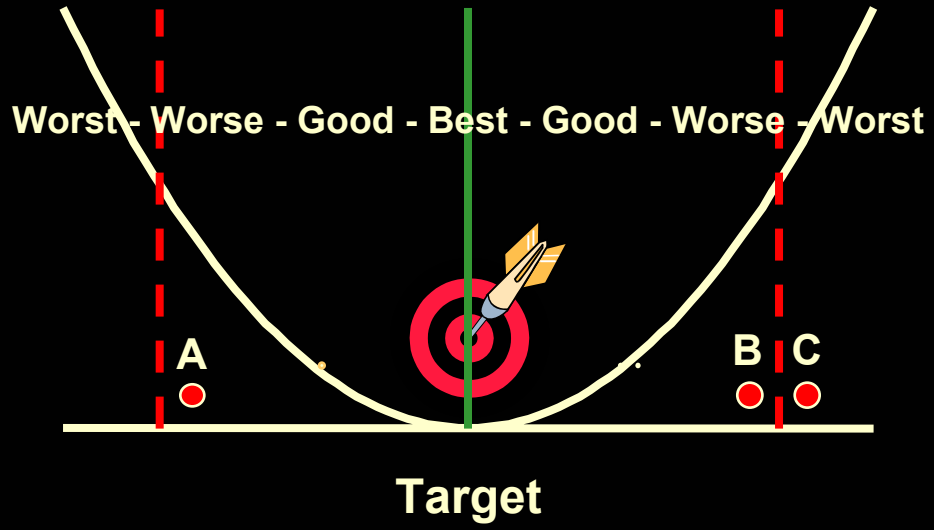


2. A deviation of the overall average from a desired target

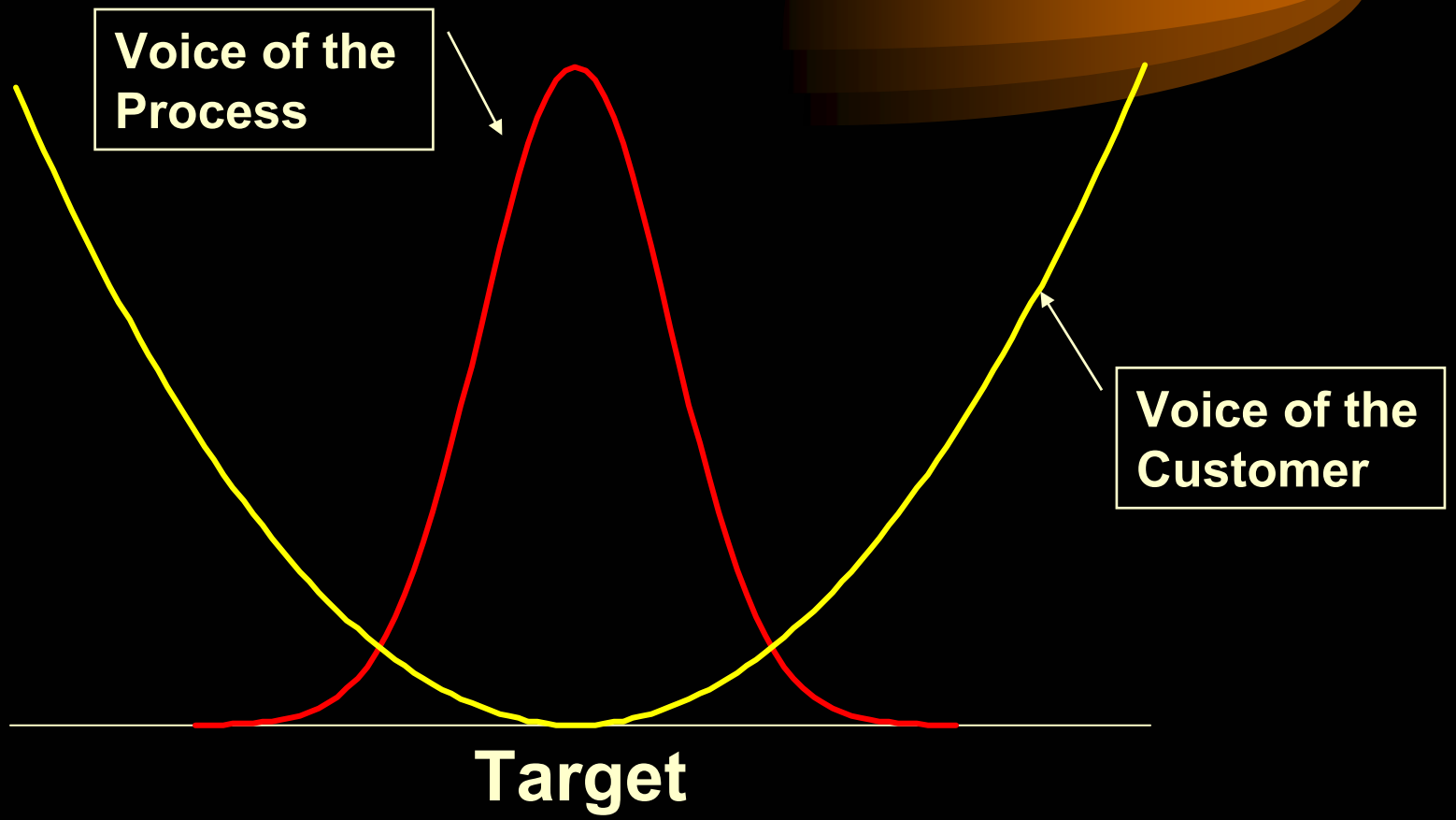


Specifications vs. Targets





Align the Voices



Understand and Reduce Variation

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Types of Variation

- Common Cause
- Special Cause
- Structural Cause

Definitions

- Common Cause
  - Variation a process would exhibit if behaving at its best
- Special Cause
  - Variation from intervention of sources external to the process
- Structural Cause
  - Inherent process variation (like common cause) that looks like special cause
  - Has a predictable onset

Common Causes

- Numerous
- Repetitive
- Originate from many sources
- Common to all the data
- Predictable in terms of a band of variation

Special Causes

- Sporadic in occurrence
- Onset often not predictable
- Originate from few sources
- Increase total variation over and above existing common causes
  - Can be one time upsets, or
  - Permanent changes to the process
- May enter or exit a process via process inputs (outside sources) or through conversion activities

Improvement for Common Causes

- All the data are relevant
  - Not just the “bad” or out of spec points
- A fundamental change is required
- Three improvement strategies:
  - Stratify
  - Disaggregate
  - Designed experimentation
- Management should initiate and lead the change effort

Improvement for Special Causes

- Work to get very timely data
- Immediately search for cause when control chart gives a signal
- No fundamental process changes
- Seek ways to change some higher level process
  - Maintain good special causes
  - Prevent recurrence of undesirable special causes

Questions to Help Distinguish Between Special and Common Causes

- Did this happen because we got caught and were unlucky, or did something or someone specifically cause it?
  - Unlucky = Common Cause
  - Specific event = Special Cause
- Could it have elsewhere, at another time, to someone else, with different materials?
  - Yes = Common Cause
  - No = Special Cause
- Was it specific to a person, material, condition or time?
  - Yes = Special Cause
  - No = Common Cause

From Heero Hacquebord

Structural Causes of Variability

- Variation that is part of the system but looks like a special cause
- Consistent difference (across space)
  - Among injection molder cavities
  - Across a coated or extruded roll
  - Around a part
- Structure over time
  - Machine wear
  - Consistent cyclic data
    - Coating roll patterns

Dealing With Structural Variation

- Remove structure if possible
  - Requires change to the process
- Use 3-Chart method
  - Structure only affects the Range chart
- Model structure and remove effect
  - Requires data analysis
  - Does not reduce process variability
  - Allows better assessment of other sources of variation

Robustness - An Underused Concept

- Key aspect of Statistical Thinking
- Reduce the effects of uncontrollable variation in:
  - Product design
  - Process design
  - Management practices
- Anticipate variation and reduce its effects

Robustness of Product and Process Design

- Another way to reduce variation
- Anticipate variation
  - Design the process or product to be insensitive to variation
- A robust process or product is more likely to perform as expected
- 100% inspection cannot provide robustness

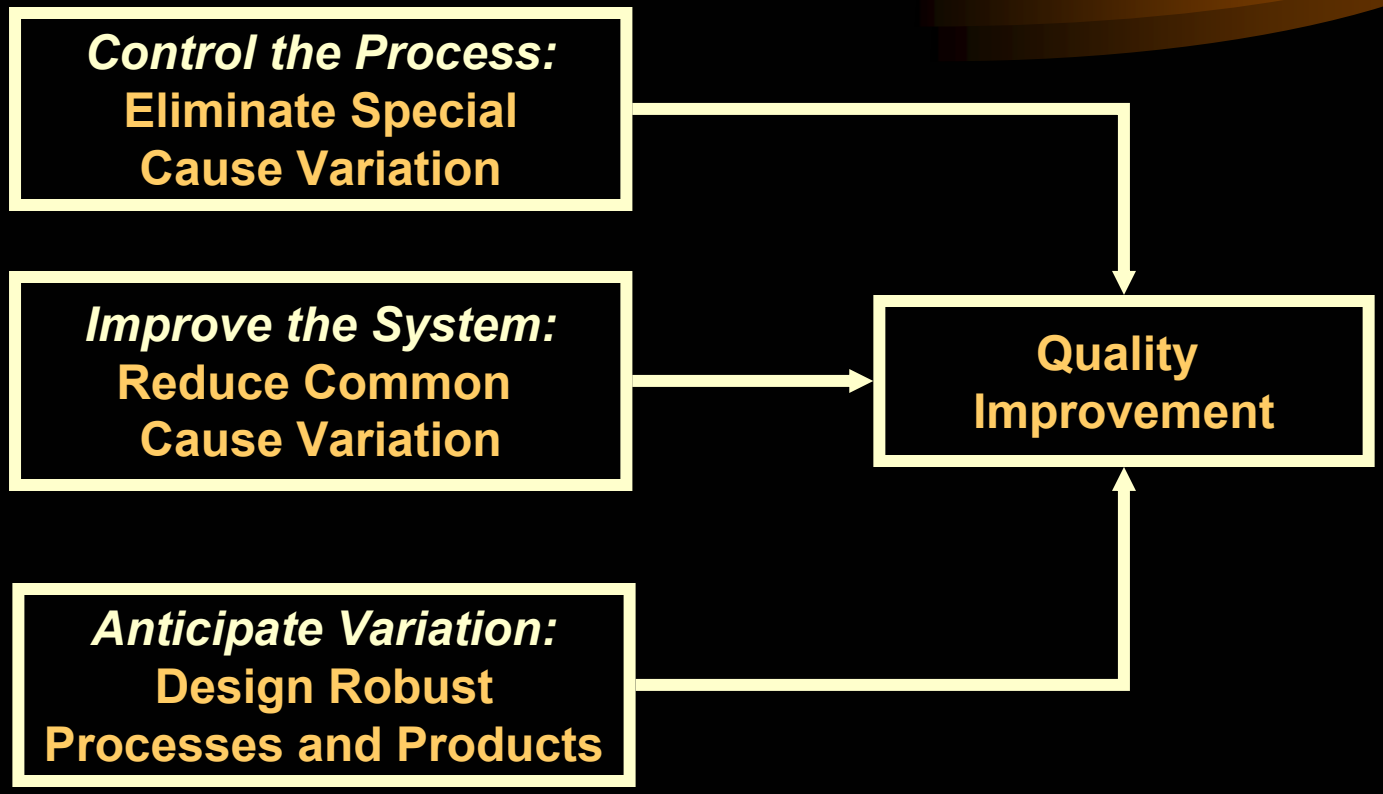
Robust Design in Anticipation of Customer Use or Abuse

- Washing machine tops
- User-friendly computers and software
- Low-maintenance automobiles
- 5 mph bumpers
- Medical instruments for home use

Process Robustness Analysis

- Identify uncontrollable factors that affect process performance
  - Weather
  - Customer use of products
  - Employee knowledge, skills, experience, work habits
  - Age of equipment
- Design process to be insensitive to factors' uncontrollable variation

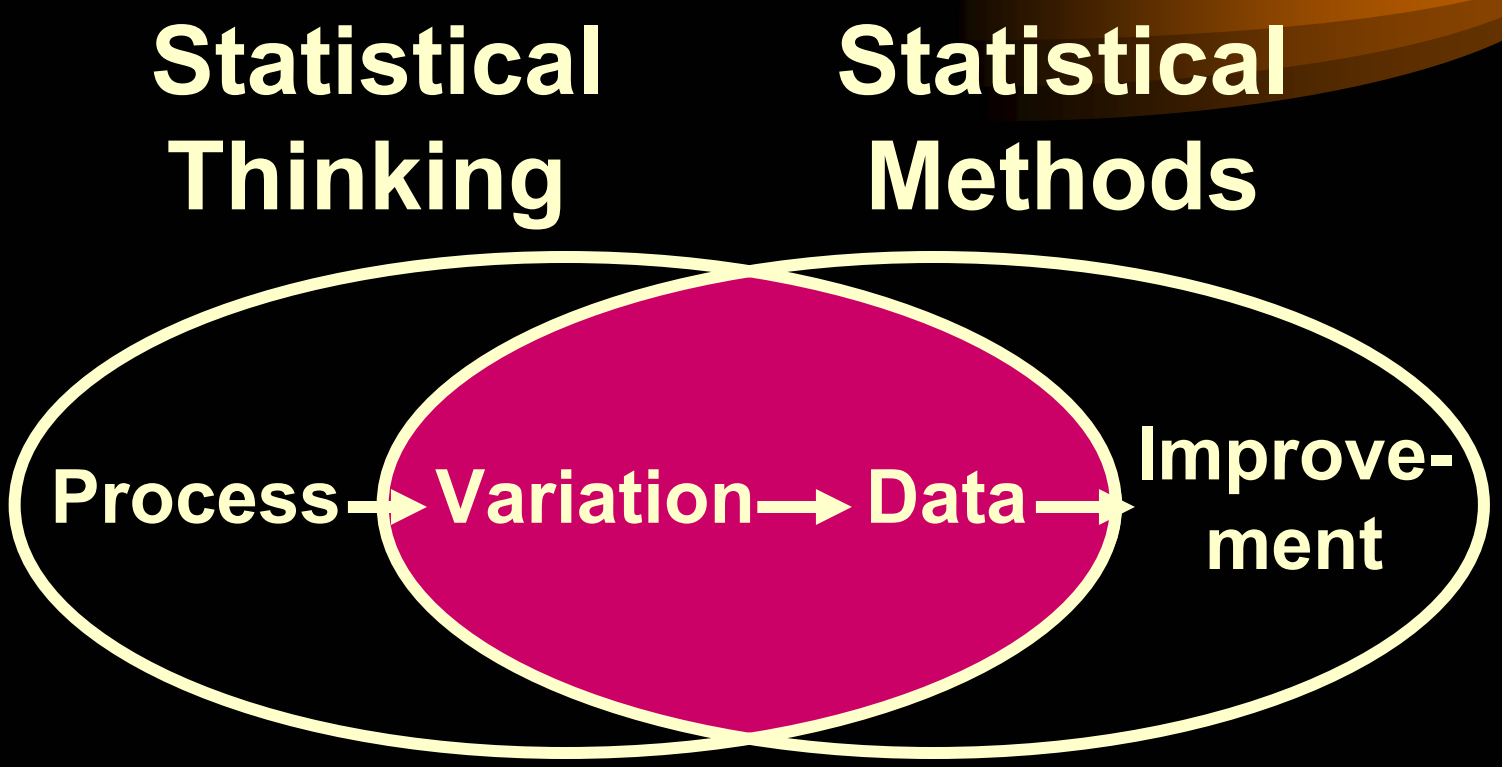
Three Ways to Reduce Variation and Improve Quality



Statistical Thinking and Statistical Methods

- Statistical thinking provides a philosophical framework for use of statistical methods.
- The framework focuses on processes, recognizing variation, and using data to understand the nature of the variation.
- Statistical methods, *when used in the context of statistical thinking*, can produce analyses that lead to action and resulting improvement.

Statistics and Improvement



Comparison of Statistical Thinking and Statistical Methods

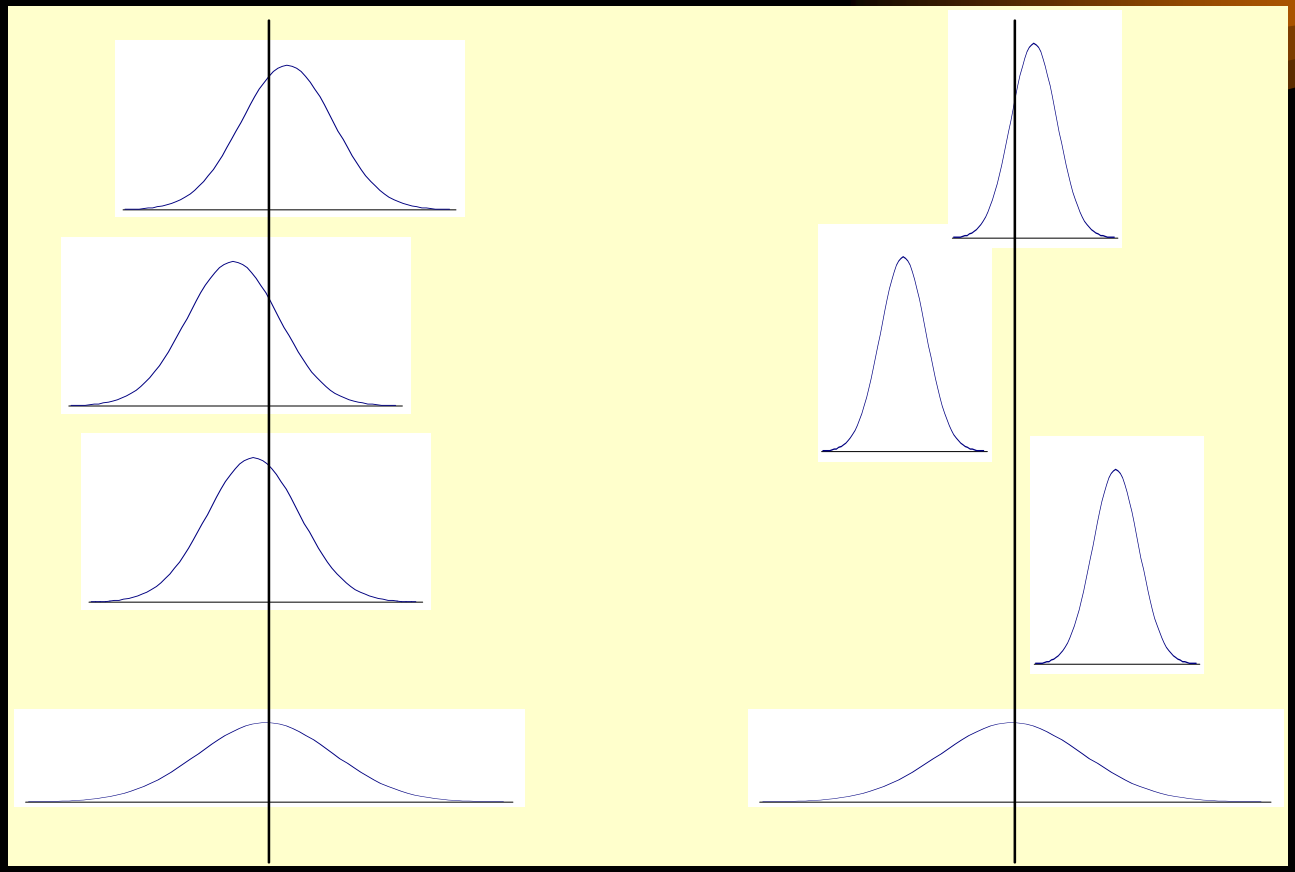
	Statistical Thinking	Statistical Methods
Overall Approach	Conceptual	Technical
Desired Application	Universal	Targeted
Primary Requirement	Knowledge	Data
Logical Sequence	Leads	Reinforces

Without a Process View

- People don't understand the problem and their role in its solution
- It is difficult to define the scope of the problem
- It is difficult to get to root causes
- People get blamed when the process is the problem (85/15 Rule)

You can't improve a process that you don't understand

Statistical Thinking - ex.: subgrouping



Within batch

Between batch

Without Data

- Everyone is an expert: discussions produce more heat than light
- Historical memory is poor
- Difficult to get agreement on
  - Definition of the problem
  - Definition of success
  - Degree of progress

Without Understanding Variation

- Management is by the last datapoint
- Fire-fighting dominates
  - Special cause methods are used to “solve” common cause problems
- Tampering and micromanaging abound
- Efforts to attain goals fail
- Process understanding is hindered
  - Learning is slowed

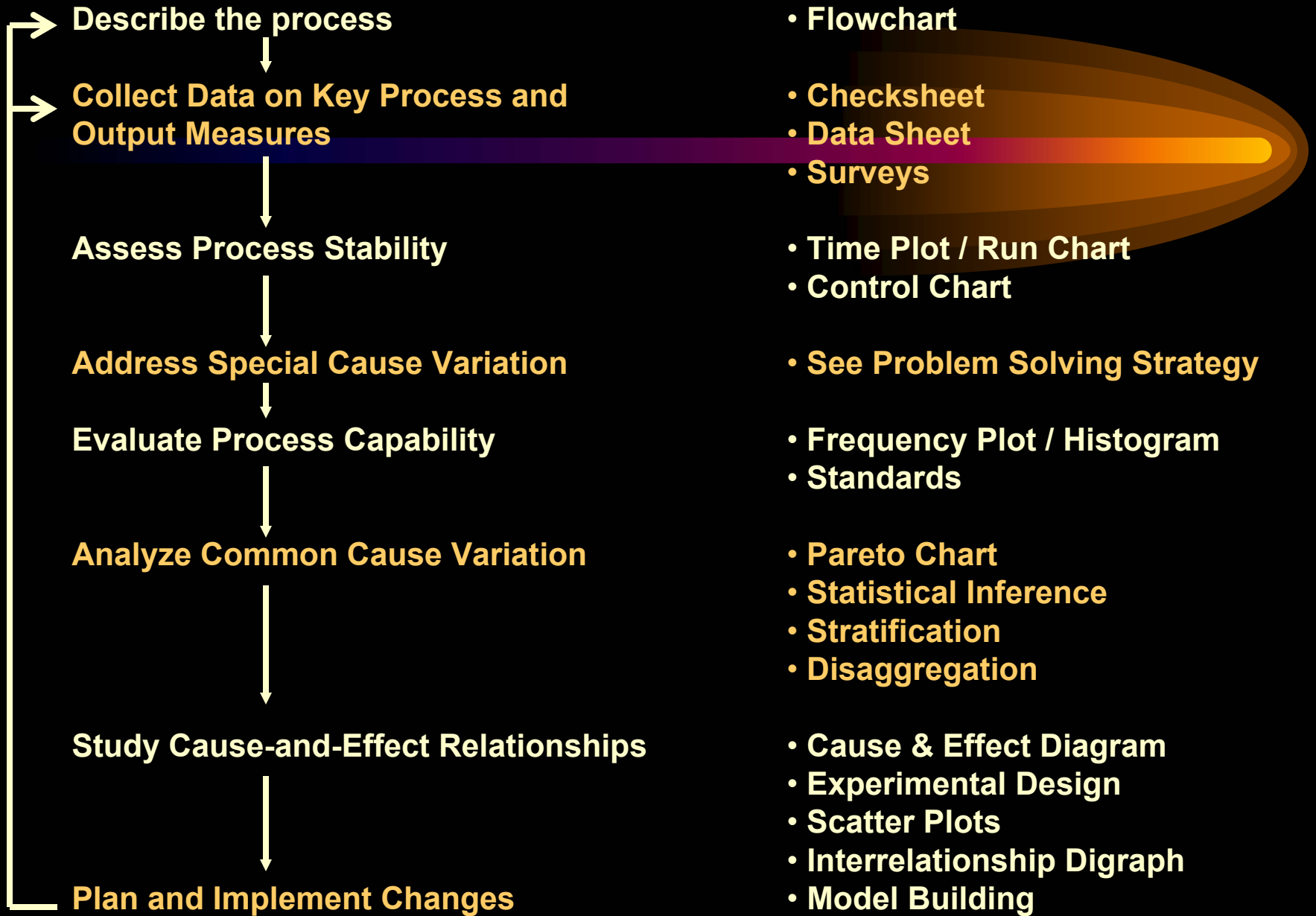
Without Statistical Thinking

- **Process management is ineffective**
- **Improvement is slowed**

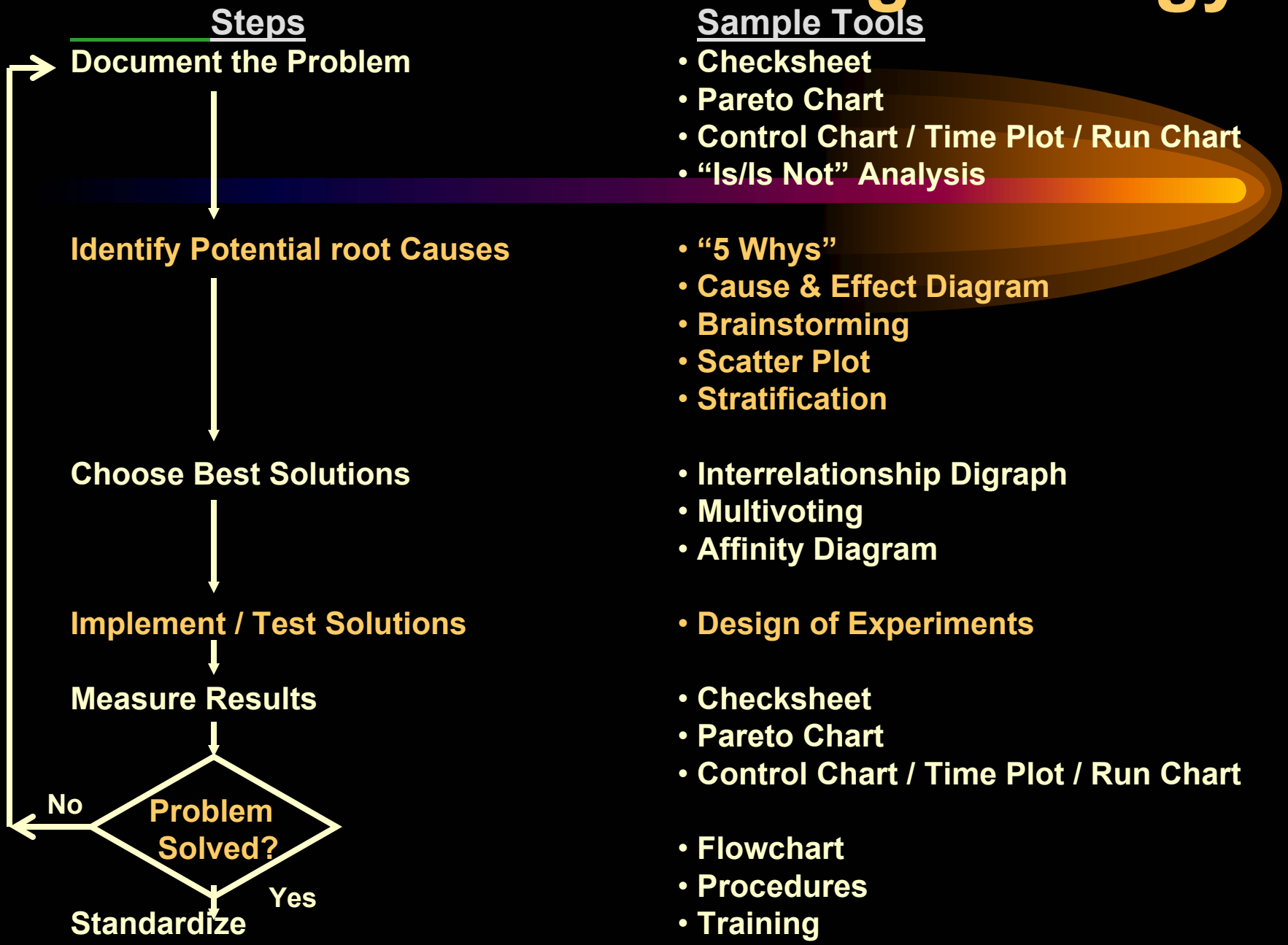
"Early on, we failed to focus adequately on core work processes and statistics."

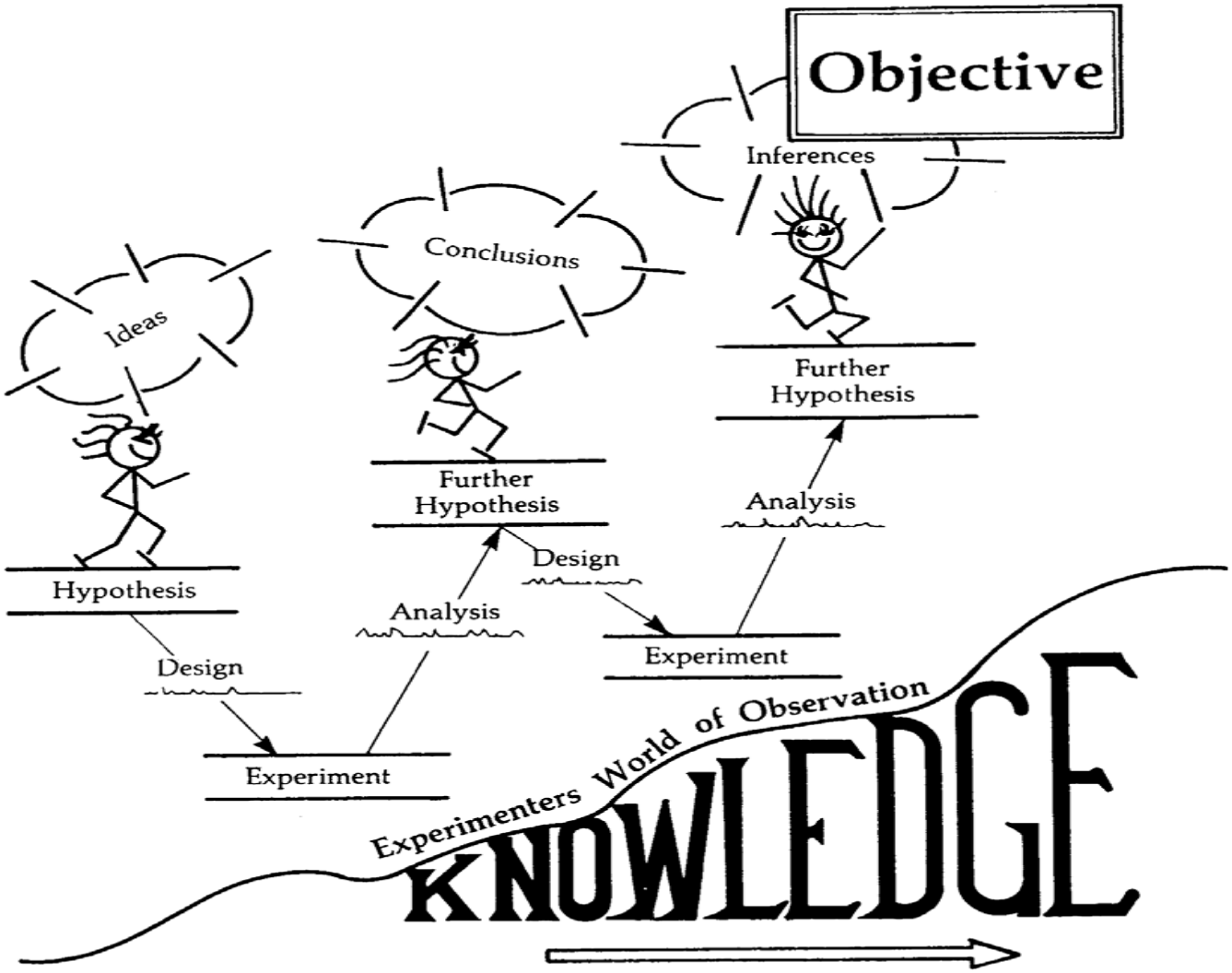
David Kearns and David Nelder, Xerox Corporation

Process Improvement Strategy



Problem Solving Strategy





The Iterative Nature
of
Experimentation

Benefits of DOE

- More Information from fewer Experiments
- Evaluation of Plausible Relationships
- Prediction of Future Results
- Optimization of Responses
- Control of Processes

Historical Data or DOE?

Historical Data

- take what you can get
- limited range
- taken over time
- correlation

Designed Experiments

- controlled conditions
- defined range
- focused time frame
- causation

What is your objective?

Adequate Design

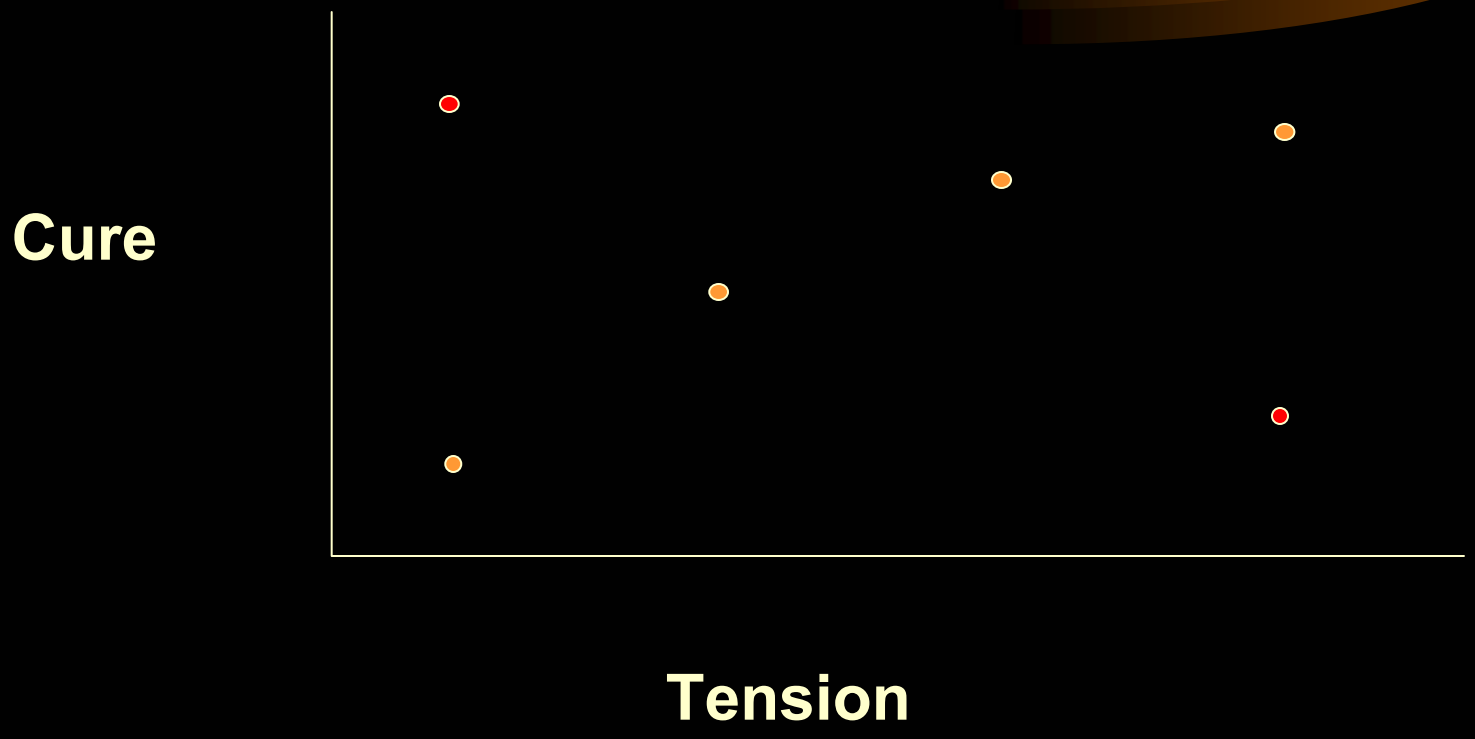
- Has stated objective with hypothesis statement
- Considers
  - Replication
  - Blocking
  - Ranges
  - Form (split plot, randomization, etc.)
- DOE Journal and Summary

Considerations for Planned Experiments

- Scope of validity
  - factors
  - ranges
  - responses
  - NOTE: adequate measurements needed for both factors and responses
- Replication
- Randomization
- Blocking

Value of Replication

Value of Replication

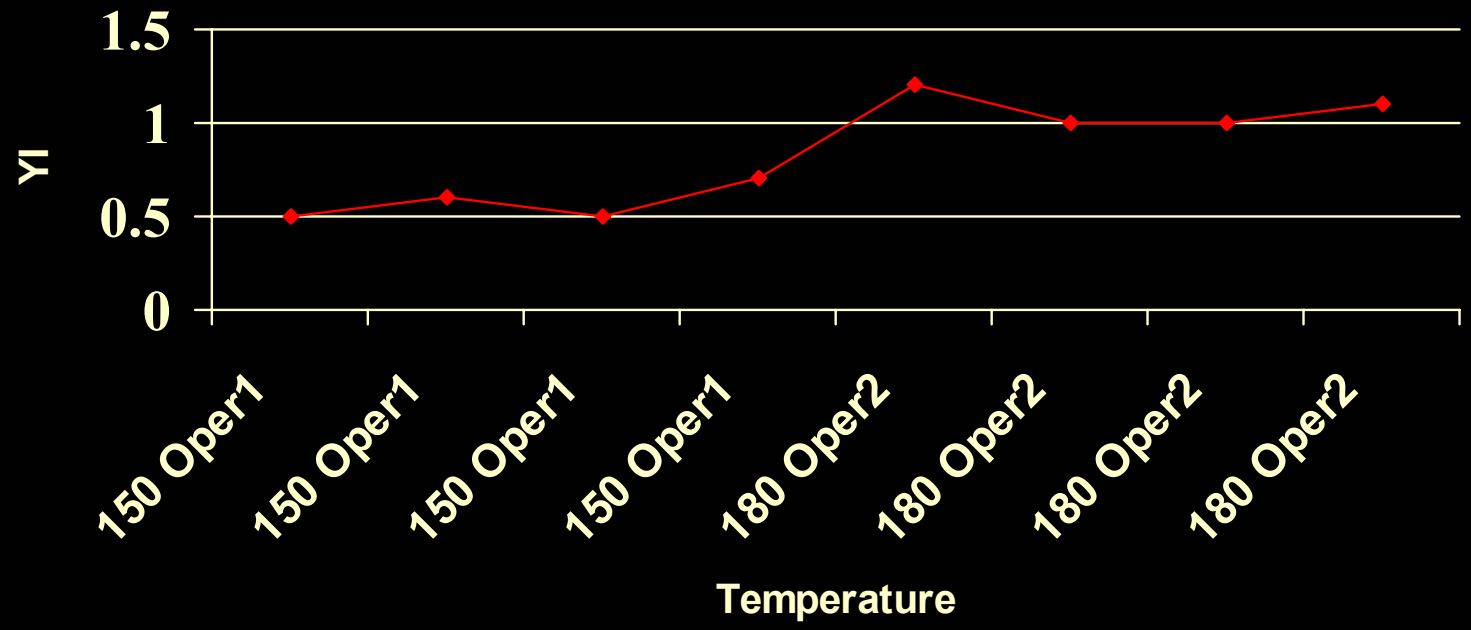


Replication

- Need “yardstick” for comparison so you know effects rise above system noise (common cause variability)
- Make sure replicates are different (e.g. Not repeat measures on same sample)
- Typically, replicates are spread throughout a series of experiments

Randomization/Blocking

- Techniques to ensure that effects are not due to outside influences



Evaluating the Results

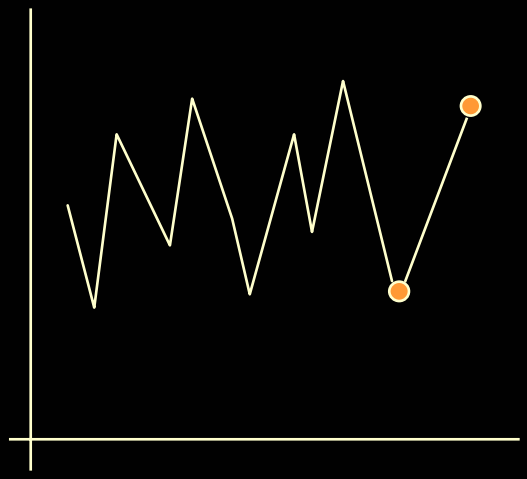
- **Are the results significant?**
  - **Statistically**
  - **Practically**

How do you know?

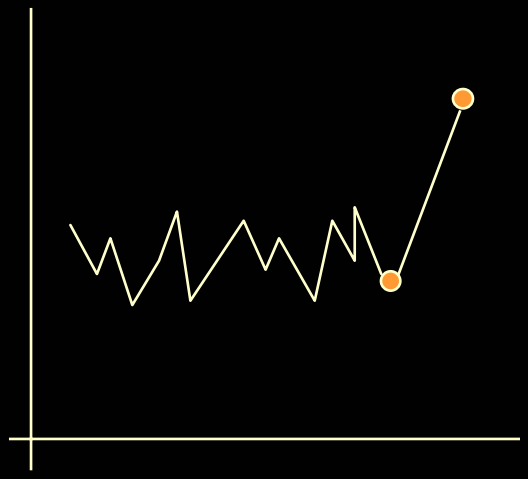
Be sure of significance before looking at plots!

Is Result Significant?

It Depends!



Common Cause



Special Cause

Your DOEs

- Do you have adequate test methods?
- Is the process stable?
- Is the design appropriate to the objective? (by the way, what is that objective?)
- Is the model significant? (low p)
- Does the model explain a large portion of the variability in the data? (high R^2)
- Does the model make sense?
- Have confirmatory runs been made?
- What next steps are suggested?