IMPROVING PERFORMANCE THROUGH STATISTICAL THINKING

Sponsored by the ASQ Statistics Division

2000 Minnesota Quality Conference

3/28/00

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Kahneman & Tversky Experiment #1

Which would you choose?

A) Take a gamble:

- 80% chance of winning $4000

- 20% chance of winning nothing

B) Take a sure thing:

(100% chance) of receiving $3000

Kahneman & Tversky Experiment #2

Which would you choose?

A) Take a gamble:

- 80% chance of losing $4000

- 20% chance of breaking even

B) Take a sure thing:

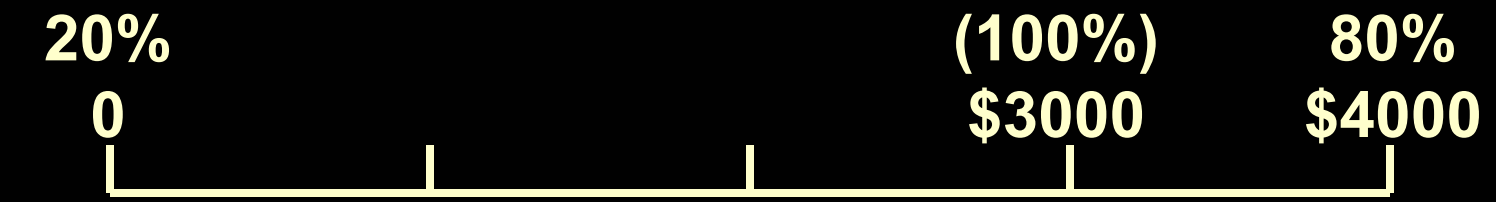
(100% chance) of losing $3000

Kahneman & Tversky

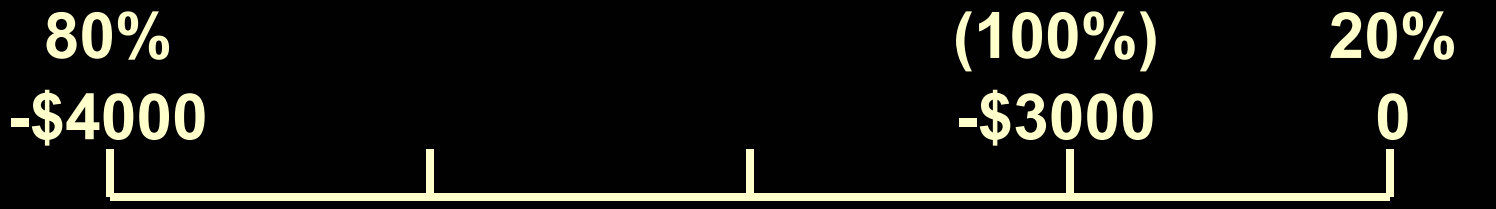
Prospect Theory

- Risk Experiments -

Experiment 1



Experiment 2



Kahneman & Tversky: "Prospect Theory" Findings

- **We tend to be inconsistent in the way we make decisions involving gains versus decisions involving losses.**
  - **When the choice involves gains, we are risk-averse.**
  - **When the choice involves losses, we are risk-takers.**
- **We tend to be driven mostly by "loss aversion"**

Source: *Against the Gods* by Peter L. Bernstein

Outline

- Introduction and motivation - 45 minutes
- What is Statistical Thinking? - 3 hours
- Lunch
- How can I apply Statistical Thinking effectively in my organization? - 3 hours
- Summary - 15 minutes

Note: All sessions (except the summary) will involve interactive team breakouts. We are not smart enough to tell you the answers!

I. Introduction and Motivation

Overall Goal

- **To better prepare attendees to apply Statistical Thinking effectively within their own organizations, to deliver improved results**
- **To identify ways to get management to lead it**

Objectives

- Obtain a common understanding of Statistical Thinking, its definition, and its application
- Clarify the distinction between Statistical Thinking and statistical methods
- Provide practice applying Statistical Thinking to real situations
- Provide attendees the opportunity to address implementation issues specific to their situations

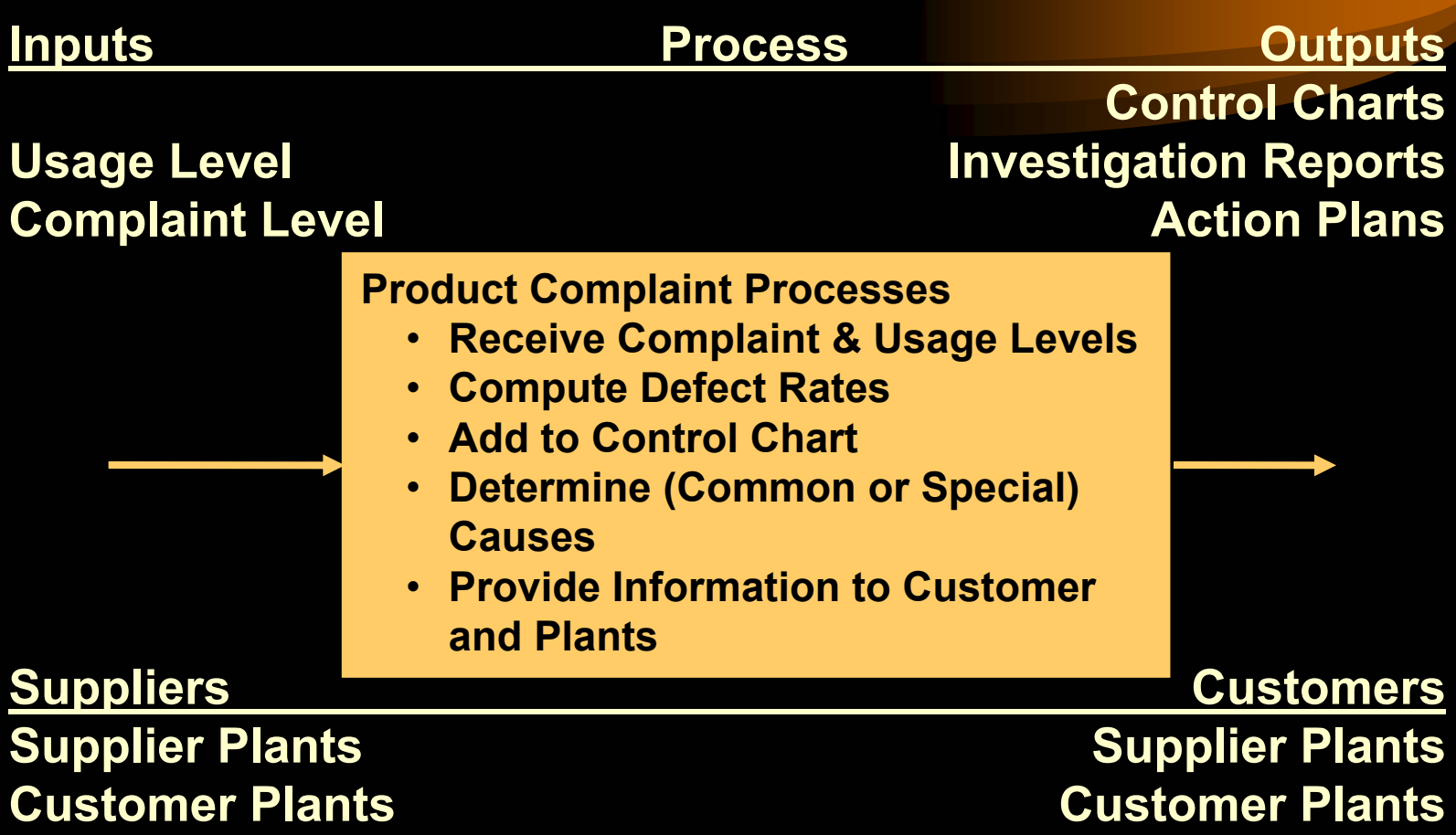
Example: Customer Complaints

Month	% Reject
Jan-91	.001
Feb-91	.032
Mar-91	.024
Apr-91	.019
May-91	.012
Jun-91	.030
Jul-91	.019
Aug-91	.021
Sept-91	.029
Oct-91	.092
Nov-91	.060
Dec-91	.036

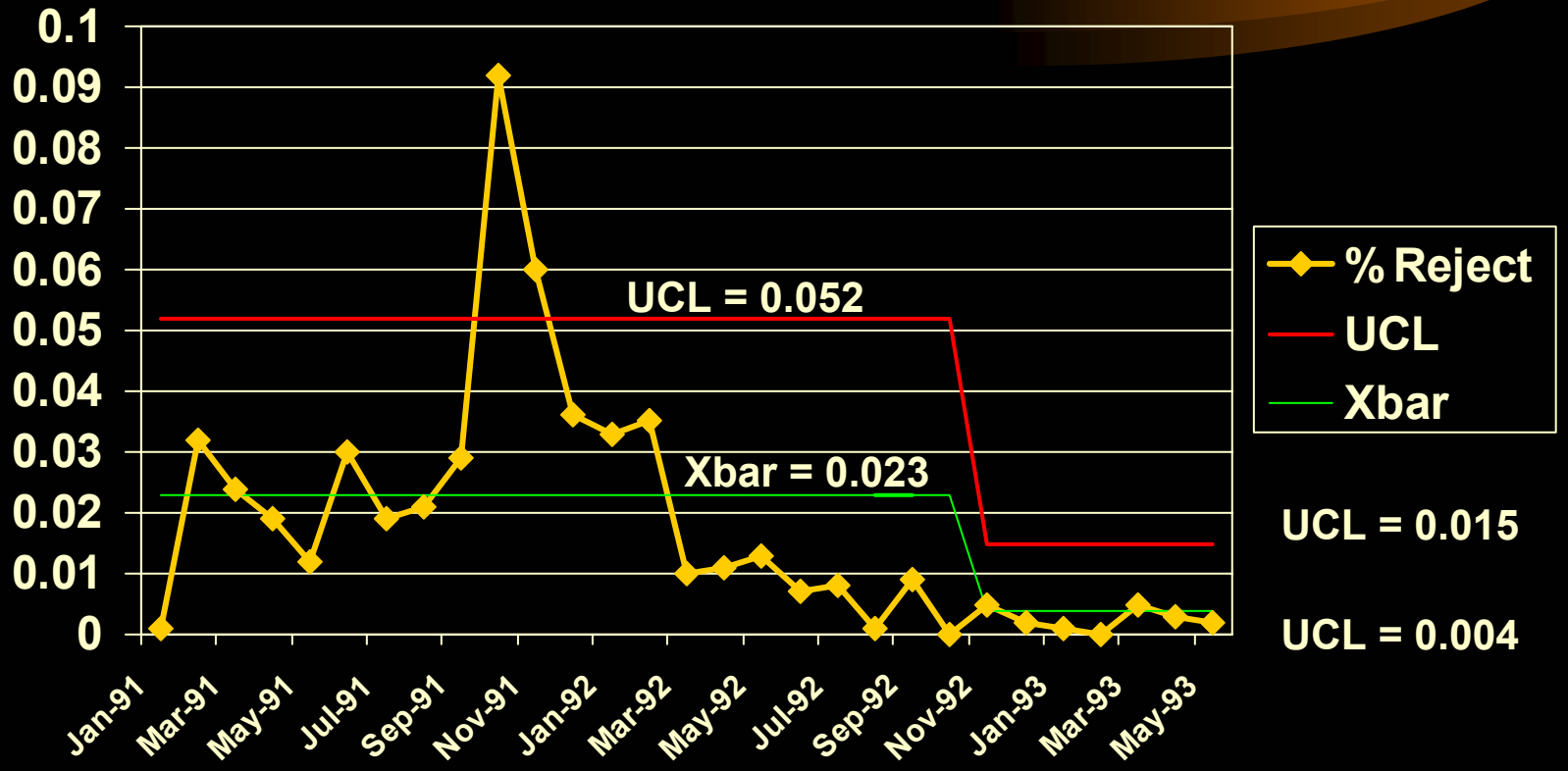
Month	% Reject
Jan-92	.033
Feb-92	.035
Mar-92	.010
Apr-92	.011
May-92	.013
Jun-92	.007
Jul-92	.008
Aug-92	.001
Sept-92	.009
Oct-92	.000
Nov-92	.005
Dec-92	.002

Month	% Reject
Jan-93	.001
Feb-93	.000
Mar-93	.005
Apr-93	.003
May-93	.002

Flowchart of a Product Complaint System



Control Chart of Customer Complaints



Doug Hlavacek

Ecolab

II. 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.**

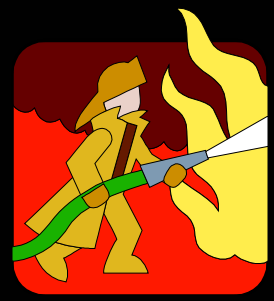
Glossary of Statistical Terms - Quality Press, 1996

Evaluation Based on Past Experiences or Perceptions

- We've always done it this way!
- We work with what we get!
- We do the best we can!
- I never thought about it!
- I'm so busy with day to day troubles, I don't have time to try that!
- Everyone knows that doesn't affect the product (or service)!

Evaluation Based on Data

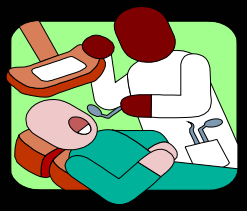
- **Why is the material from the fabrication department machine so inconsistent?**
- **Why do we constantly firefight?**
- **Why does our daily output vary so much?**
- **Why does every job result in a monumental task that takes forever to complete?**



THE KEY IS TO ASK <u>WHY!!!</u>

Philosophy of Learning and Action

Statistical Thinking is a philosophy of

learning  **and action** 

based on the following fundamental principles:

Glossary of Statistical Terms - Quality Press, 1996

Systems and Processes

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

- ***All work occurs in a system of interconnected processes***

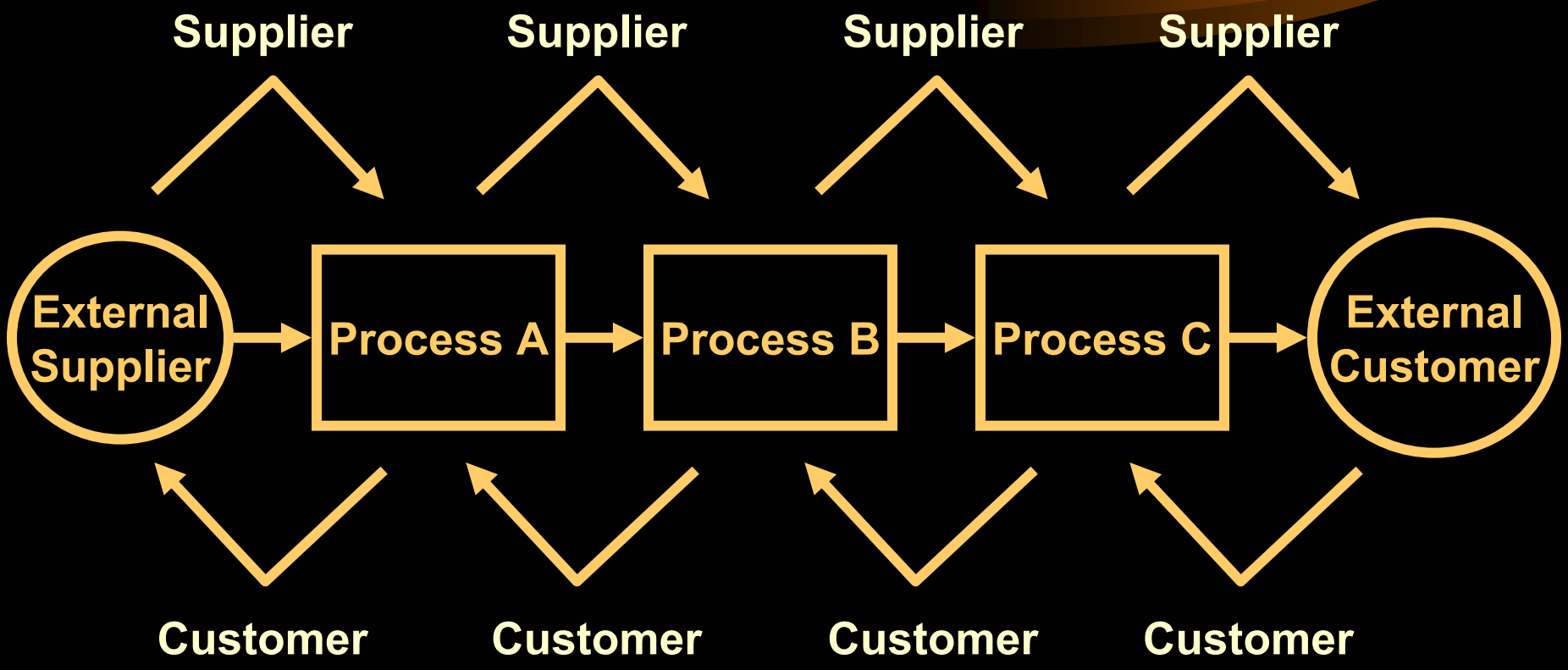
Glossary of Statistical Terms - Quality Press, 1996

Process

A series of activities that converts inputs into outputs

S I P O C

SYSTEM


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

Variation

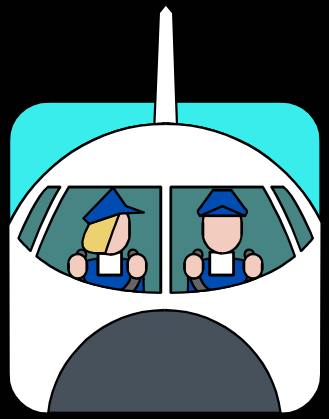
Statistical Thinking is a philosophy of learning and action based on the following fundamental principles:

- **All work occurs in a system of interconnected processes,**
- ***Variation exists in all processes***

Glossary of Statistical Terms - Quality Press, 1996

Like it or not, variation is everywhere!

- **Our drive time to work each day**
- **The quantity of production each shift**
- **Departure time of our plane**
- **…**



Know it, accept it, learn to deal with it!

Understand and Reduce Variation

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

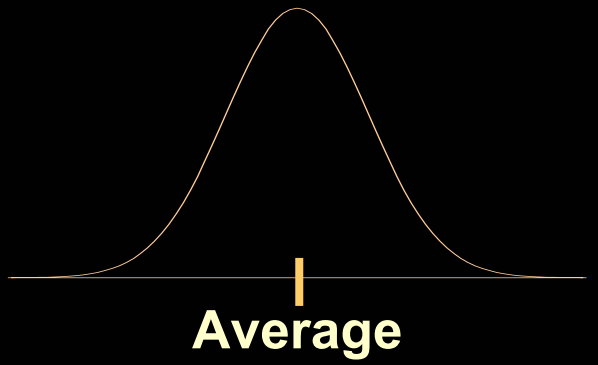
Deming once said:

If I had to reduce my message for management to just a few words, I'd say it all had to do with reducing variation.

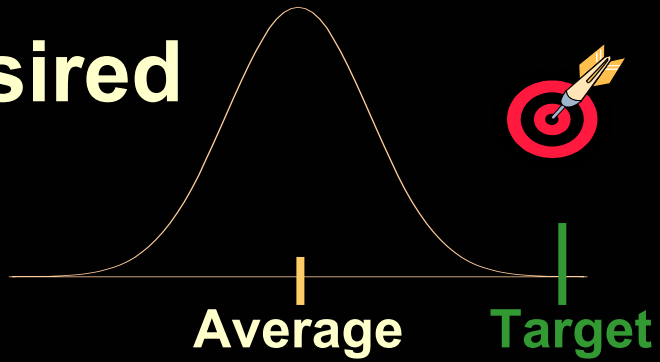
Variation and Targets

Variation can be thought of as:

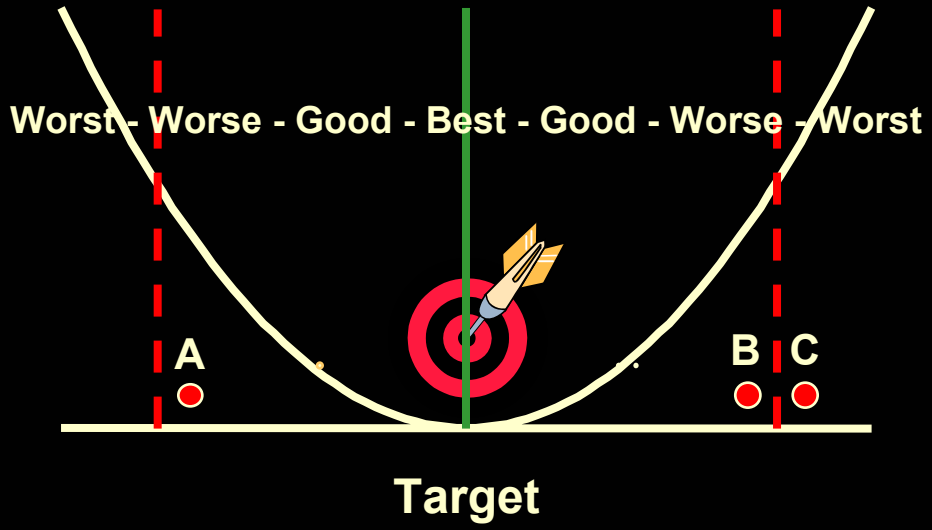
1. **Deviations around the overall average, or**



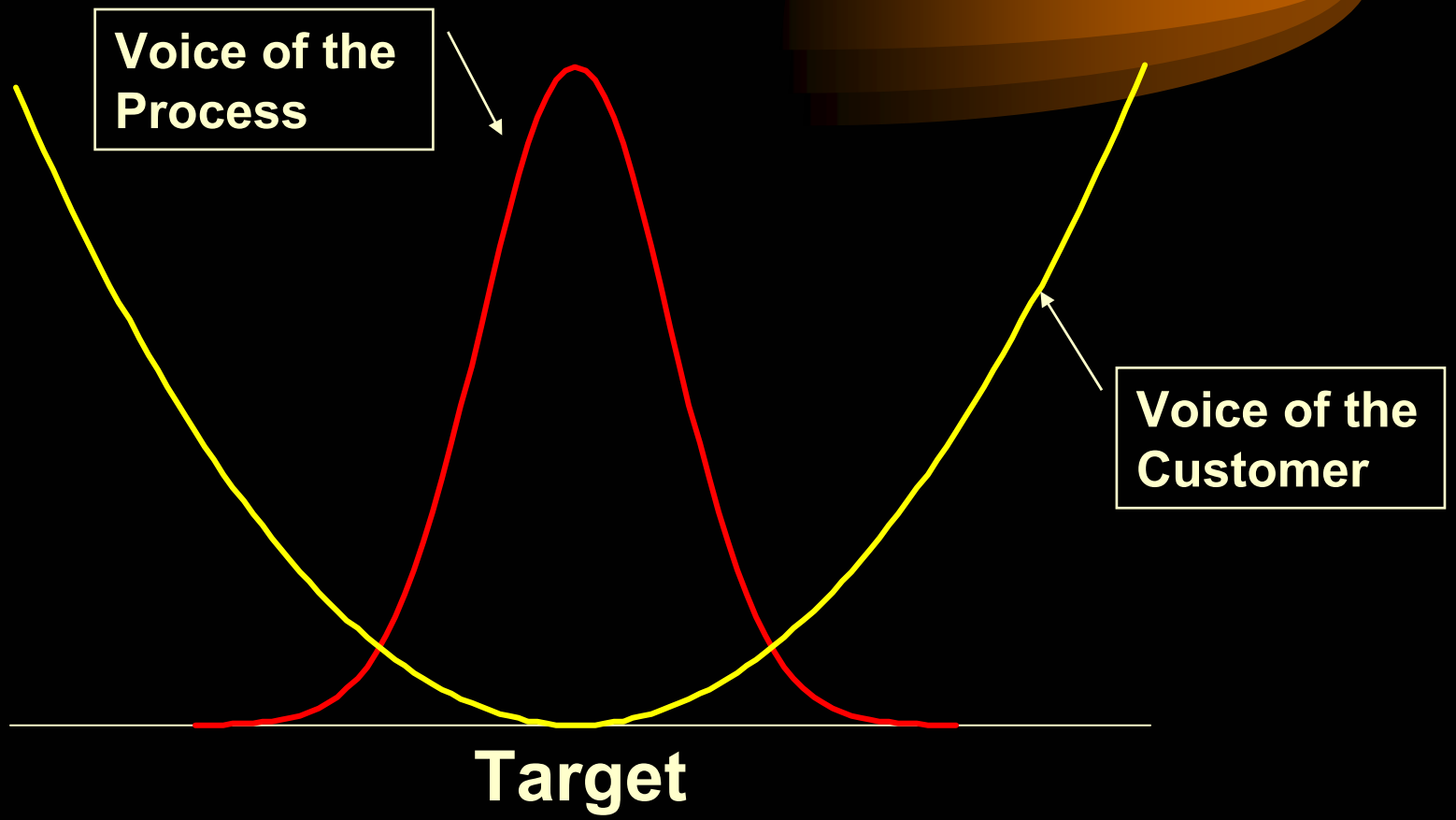
2. **A deviation of the overall average from a desired target**



Specifications vs. Targets



Align the Voices



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

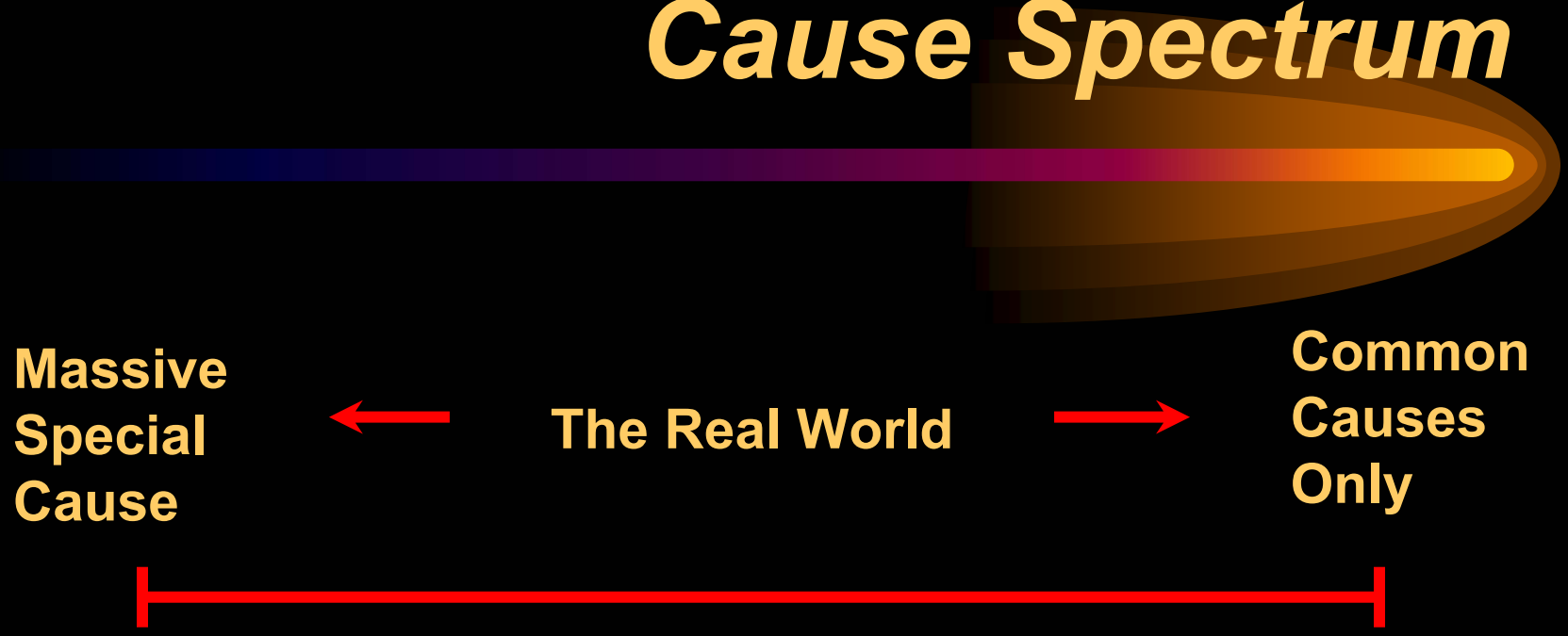
Common Causes

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

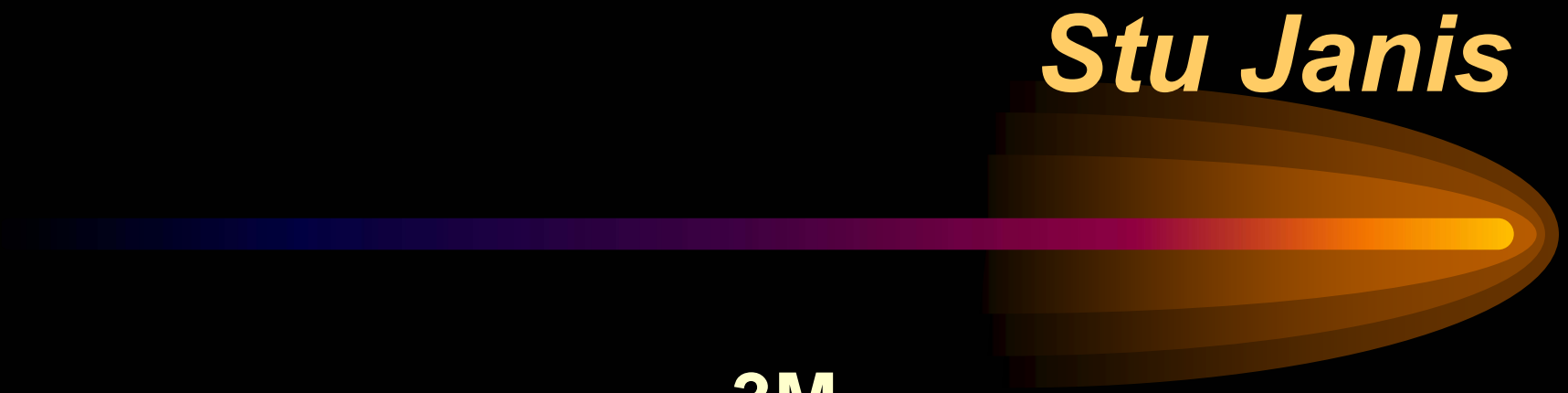
Special Causes

- 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

The Special and Common Cause Spectrum



It is important to know, at any point in time, which type of variation is dominant


Stu Janis
3M

The Get A-Head Program

Work hard

Be a winner

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**

Pitfall: Valuing Only Quantitative Data

- Qualitative data are just as important
- Example: Idea data!!

- Apply common and special cause concepts to qualitative data

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

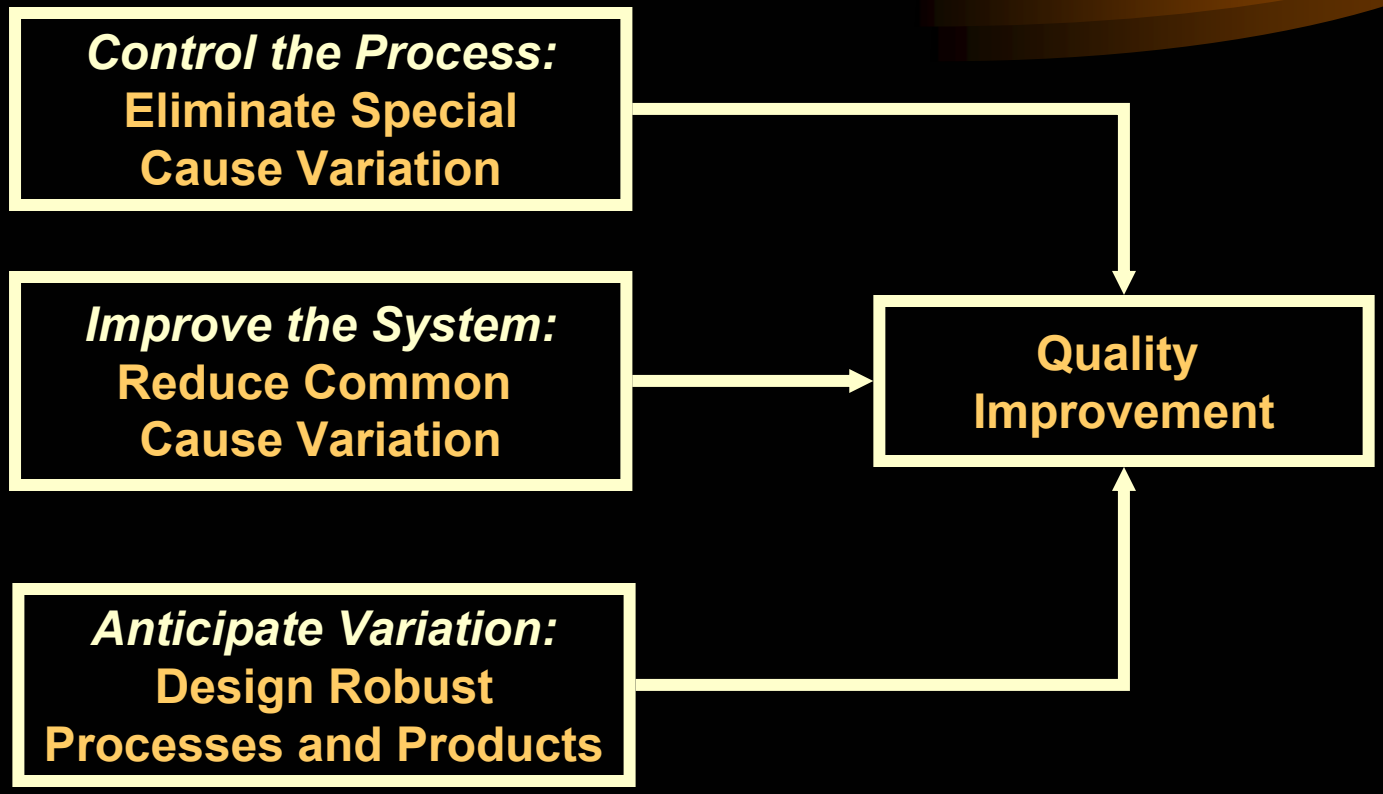
Robustness in Management

- Develop business strategies insensitive to economic trends and cycles
- Design project system insensitive to
  - Personnel changes
  - Variations in business conditions
- Respond to differing employee needs
  - Adopt flexible work hours, benefits package
- Enable personnel to adapt to changing business needs
- Ensure meeting effectiveness not dependent on facilities, equipment, or participants

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



Relation between Statistical Thinking and Statistical Methods

Steps in Implementing Statistical Thinking

All work is a process

Processes are variable

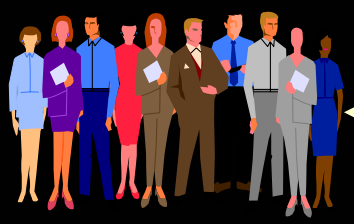
Analyze process variation

Develop process knowledge

Control process

Reduce variation

Improved quality



Satisfied:

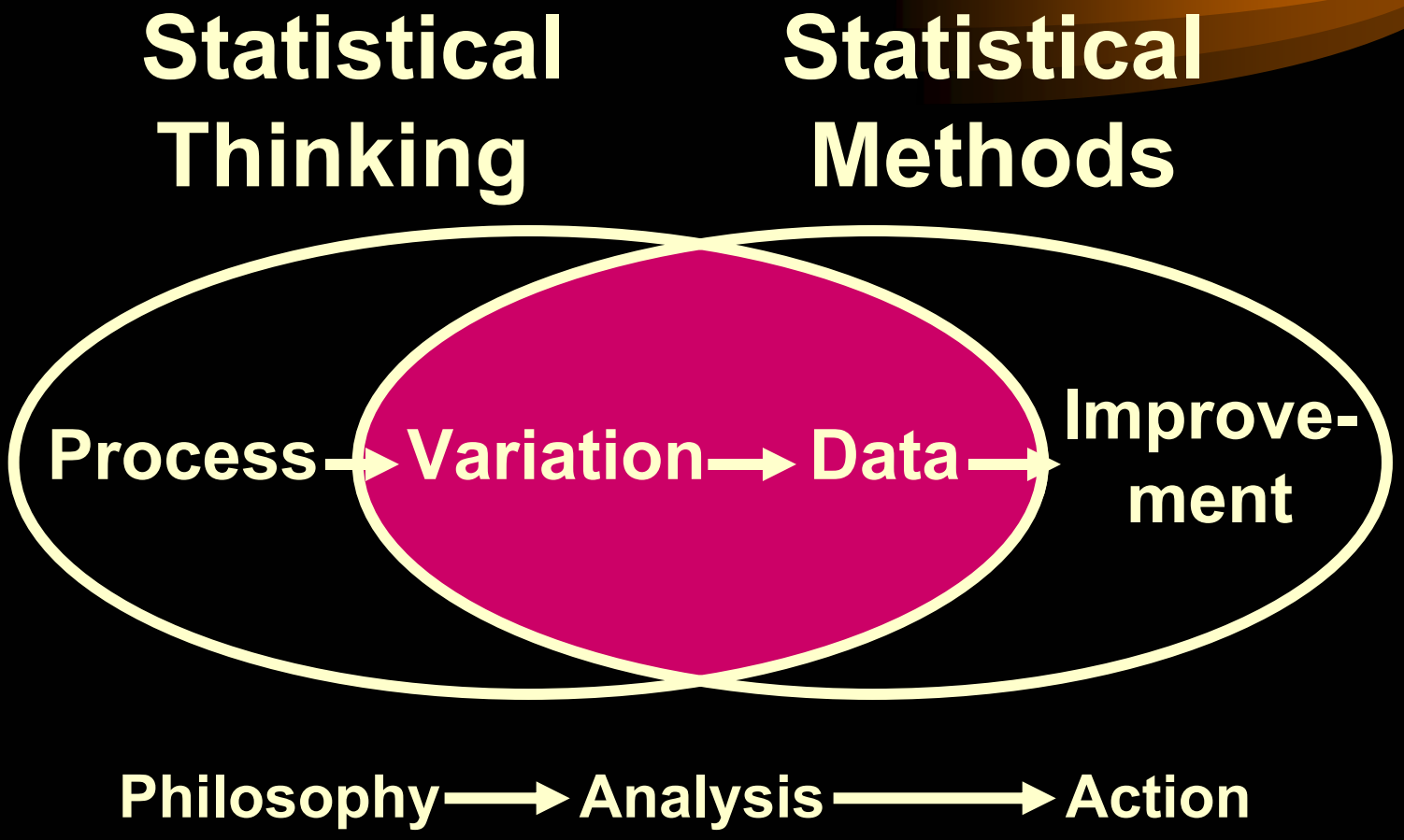
- Employees
- Customers
- Shareholders
- Community

Change process

Statistical Thinking

- **Key Concepts**
  - **Think processes and systems**
  - **Recognize variation**
  - **Analyze to increase knowledge**
  - **Take action**
  - **Improve**
- **Role of Data**
  - **Quantify variation**
  - **Measure effects**

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

How Could Statistical Thinking Benefit Your Organization?

IDEAS


Bob Mitchell
3M

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

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

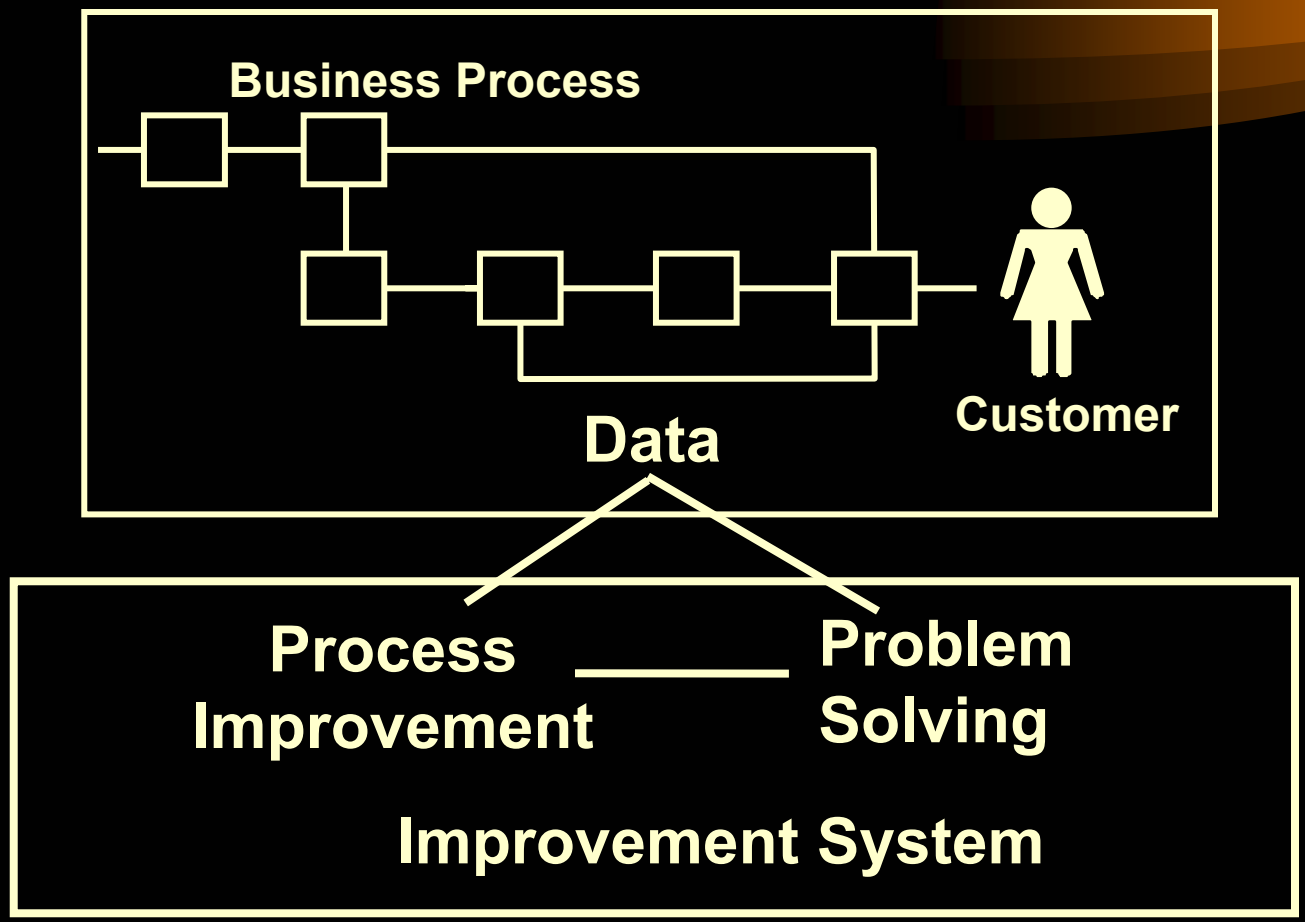
Without Statistical Thinking

- **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

Improvement Model



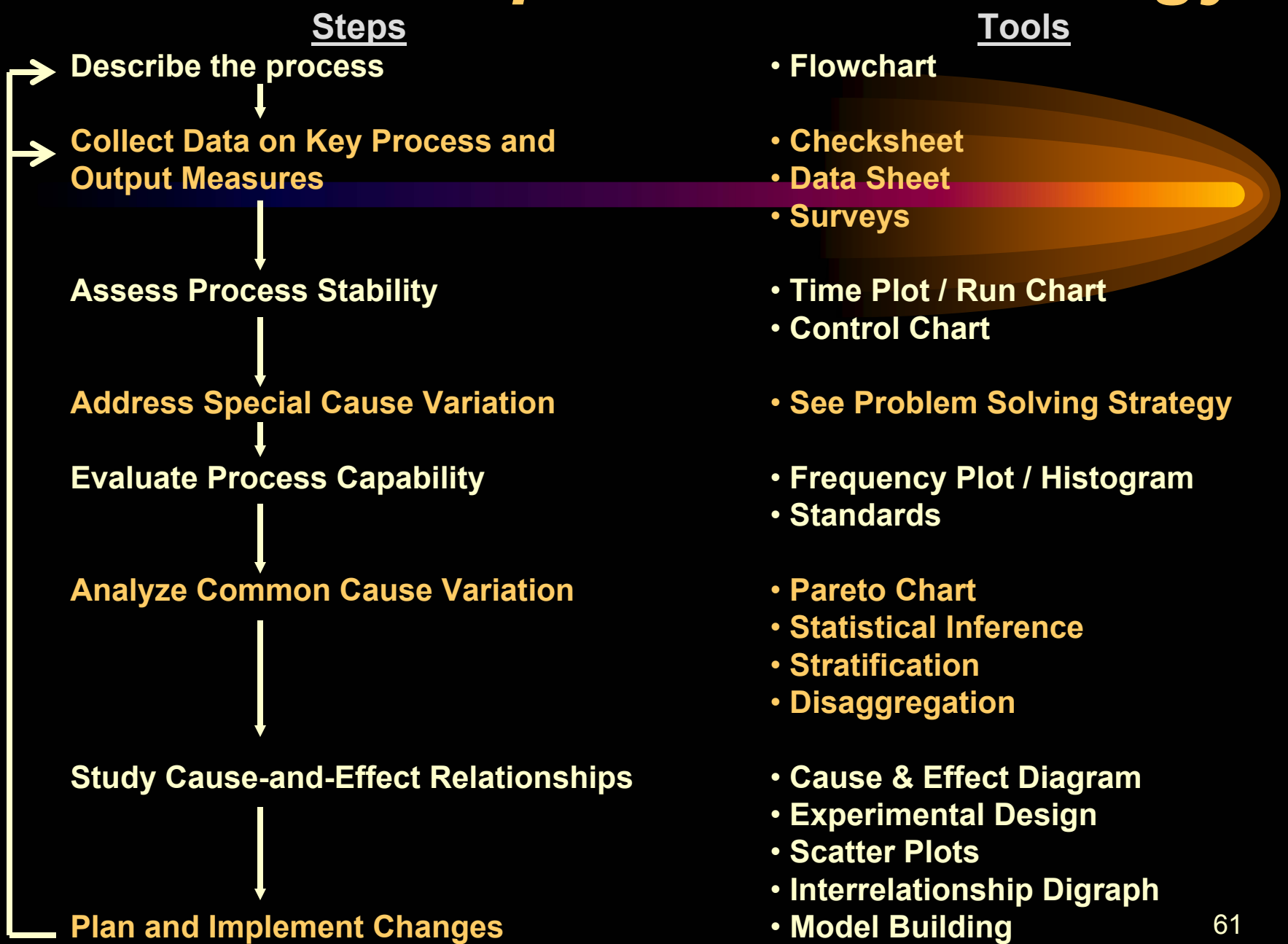
Improvement for Common Causes

- 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

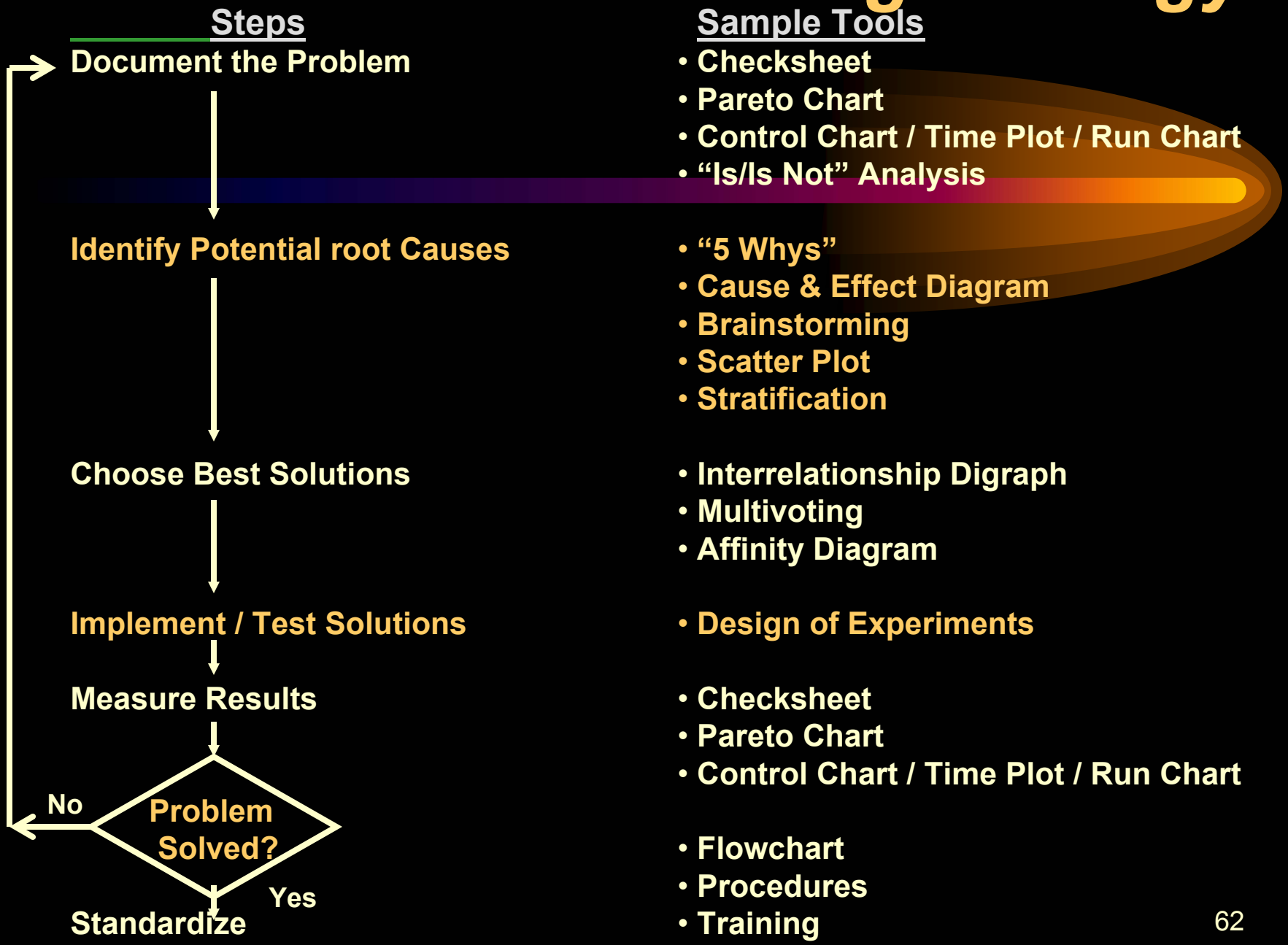
Improvement for Special Causes

- 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

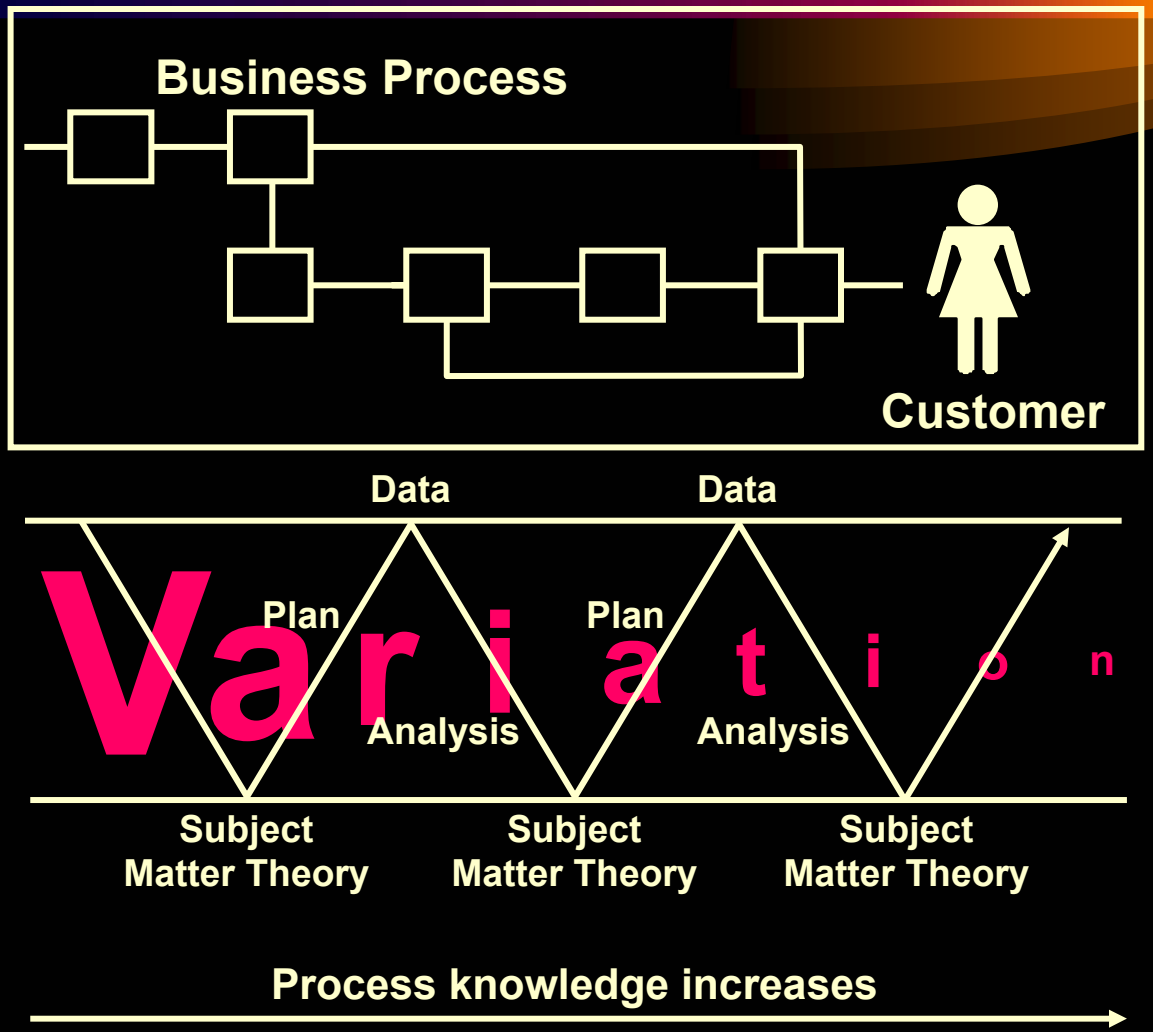
Process Improvement Strategy



Problem Solving Strategy



Statistical Thinking for Business Improvement

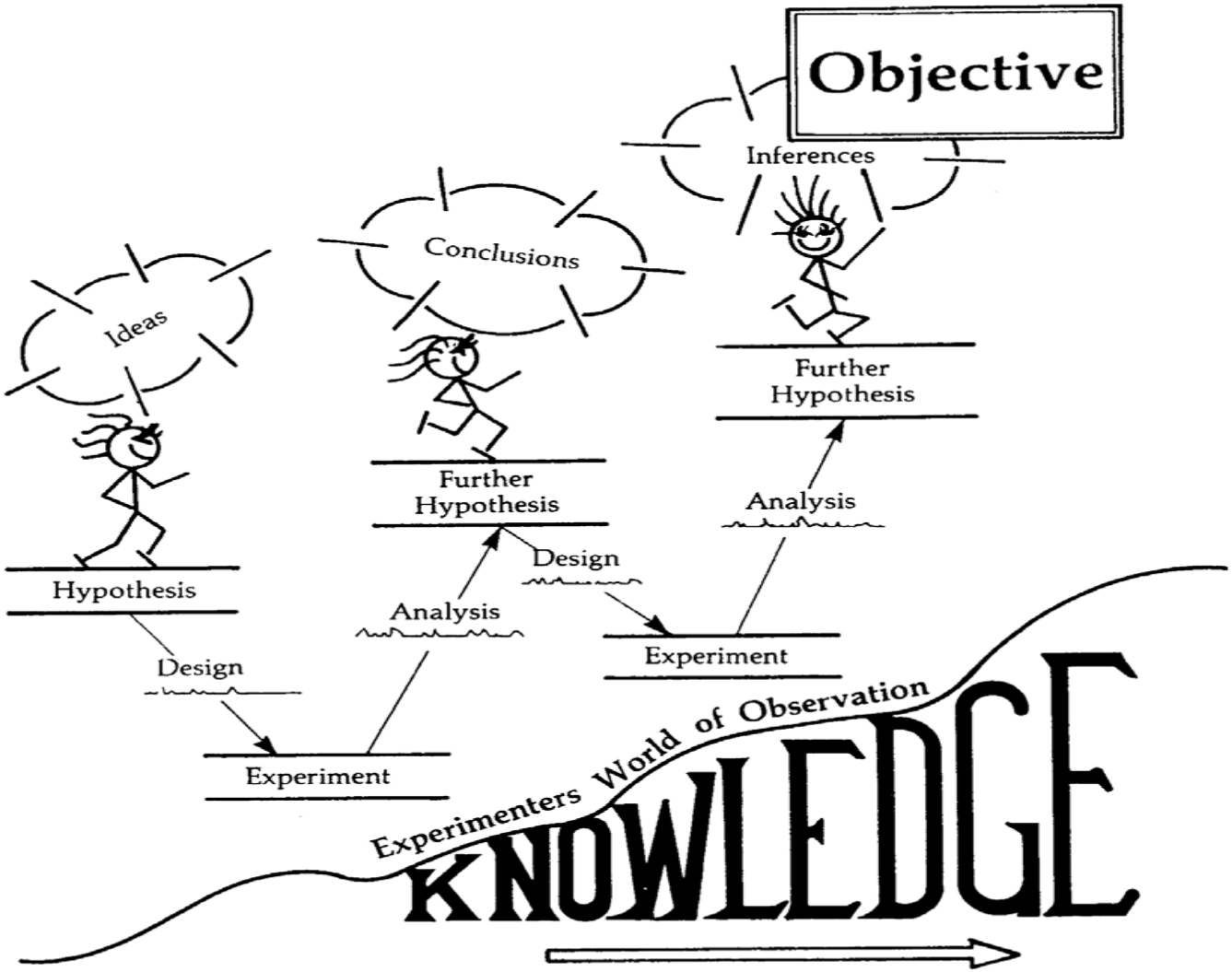


Statistical Thinking and 6 Sigma

"Six sigma is based on the scientific method utilizing statistical thinking and methods. Statistical thinking, therefore, is fundamental to the methodology."

Ron Snee

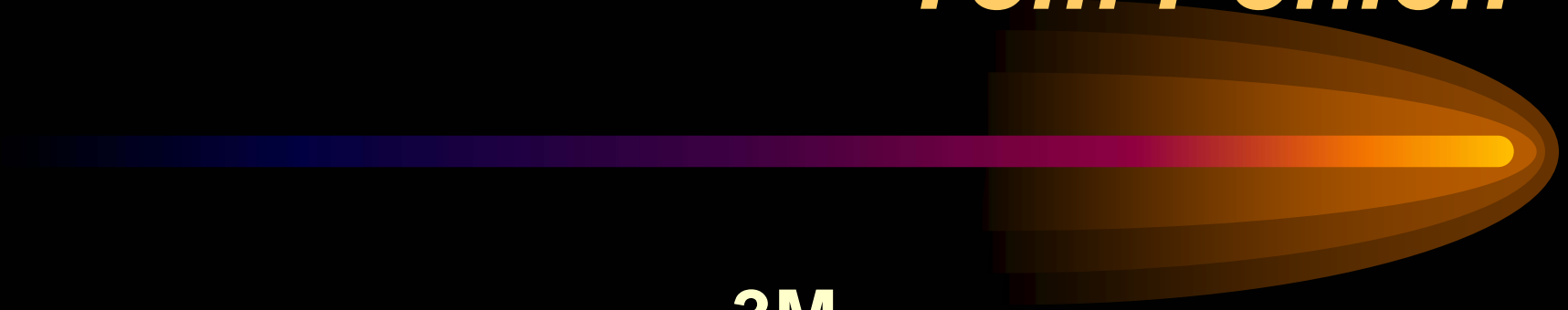
Quality Progress, September 1999



The Iterative Nature
of
Experimentation

Using Statistical Thinking Without Numerical Data

- Reduce the number of suppliers
- Reduce tampering, micro-management, and over-control
- Use meeting management techniques
- Create project management systems
- Create, monitor, and update plans


Tom Pohlen
3M

Two Case Studies

- Where's the Beef? (Page 143)
- Golden Acres (Page 144)

Group Discussions: (15 Min.)

Reports: (7 Min. each)

Applications of Statistical Thinking

Where's the Beef?

Golden Acres

Use of Statistical Thinking

Depends on levels of activity and job responsibility

Where we're headed	Strategic	Executives
Managerial processes to guide us	Managerial	Managers
Where the work gets done	Operational	Workers

Examples of Statistical Thinking at the Strategic Level

- Executives use systems approach
- Core processes flowcharted
- Strategic direction defined and deployed
- Measurement systems in place
- Employees and customers drive improvement
- Experimentation is expected

Examples of Statistical Thinking at the Managerial Level

- Standardized project management systems in place
- Project process and results are reviewed
- Variation considered when setting goals
- Measurement viewed as a process
- Reduced number of suppliers
- Variety of communication media are used

Examples of Statistical Thinking at the Operational Level

- **Work processes flowcharted and documented**
- **Key measurements identified**
  - **Time plots displayed**
- **Process management and improvement use:**
  - **Knowledge of variation**
  - **Data**
- **Improvement activities focus on the process, not blaming employees**

Statistical Thinking Applications at Strategic and Managerial Levels

Brainstorm applications of Statistical Thinking at the strategic and managerial levels in your company

Group Discussions: (15 Min.)

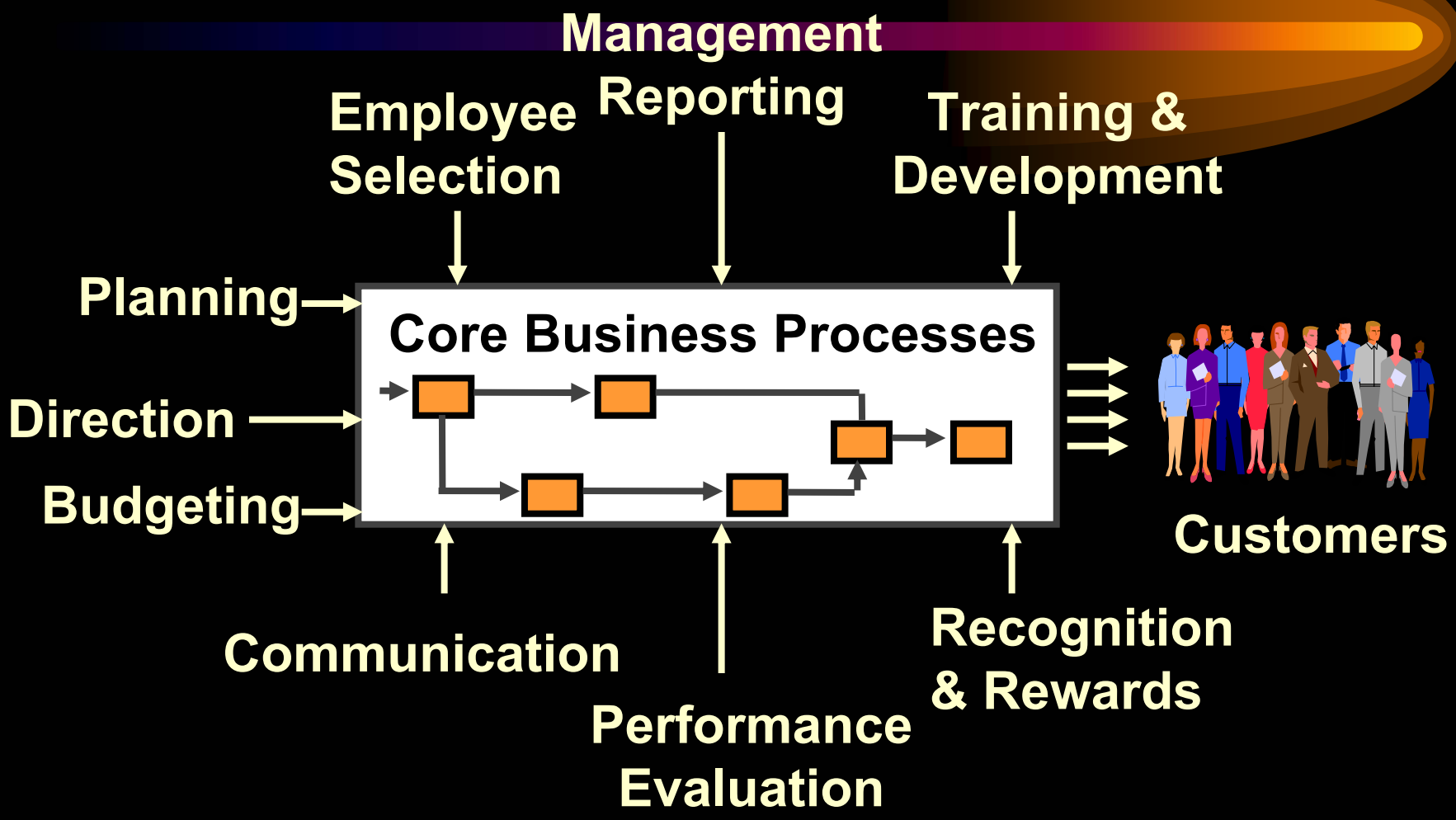
Reports: (7 Min. each)

Applications of Statistical Thinking

Strategic

Managerial

Managerial Processes



LUNCH

Doug Hlavacek

Ecolab

BRAIN TEASER

Bob and Carol and Ted and Alice

Bob, Carol, Ted and Alice are sitting around a table discussing their favorite sports.

a. Bob is sitting directly across from the jogger
b. Carol is to the right of the racquetball player
c. Alice sits across from Ted
d. The golfer sits to the left of the tennis player
e. A man is sitting on Ted's right

What sport does each of the four prefer?

SOLUTION

Alice

(Racquet ball)

Carol

(Jogger)

Bob

(Tennis)

Ted

(Golf)

Two Case Studies

- **Right Illness, Wrong Prescription (Page 145)**
- **Sales Rep of the Year (Page 147)**

Group Discussions: (15 Min.)

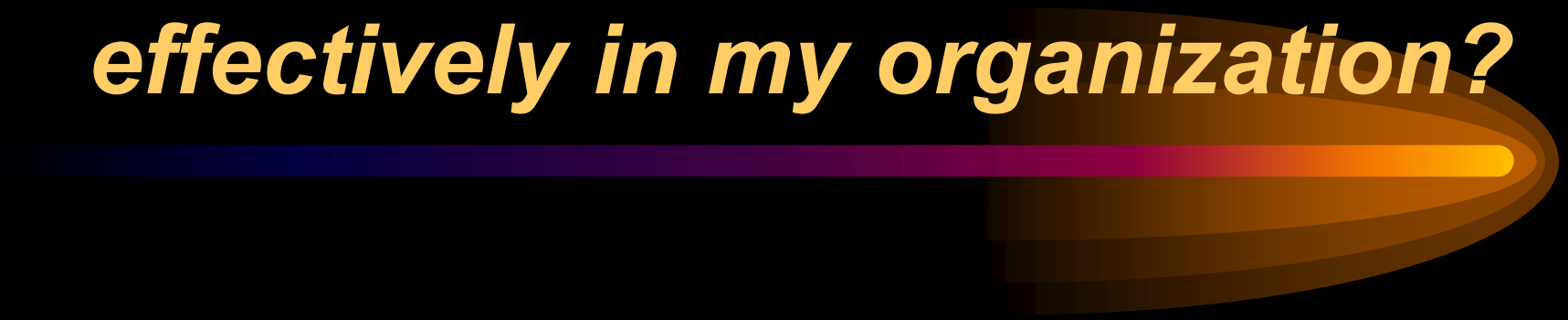
Reports: (7 Min. each)

Applications of Statistical Thinking

Right Illness, Wrong Prescription

Sales Rep of the Year

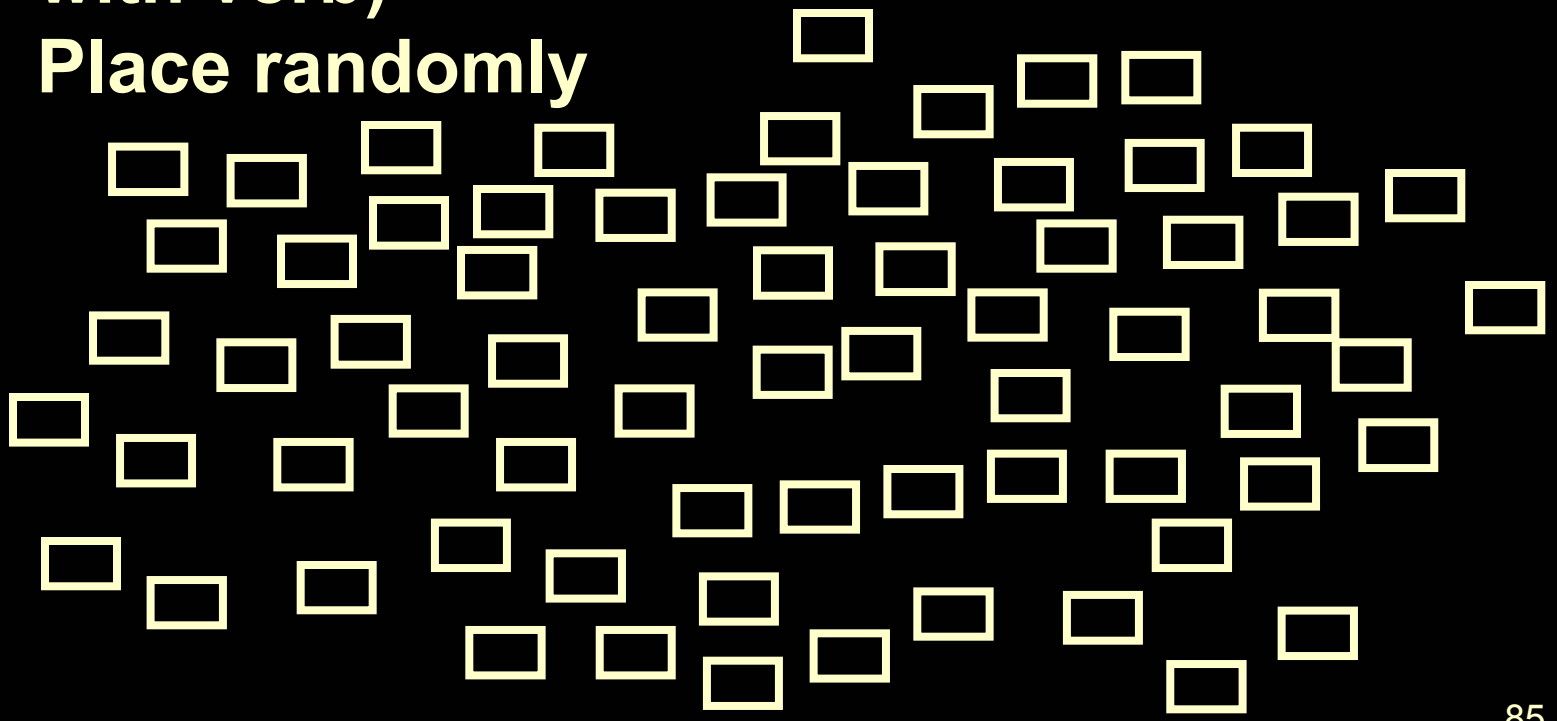
III. How can I help implement Statistical Thinking effectively in my organization?



What barriers stand between my organization and the implementation of Statistical Thinking?

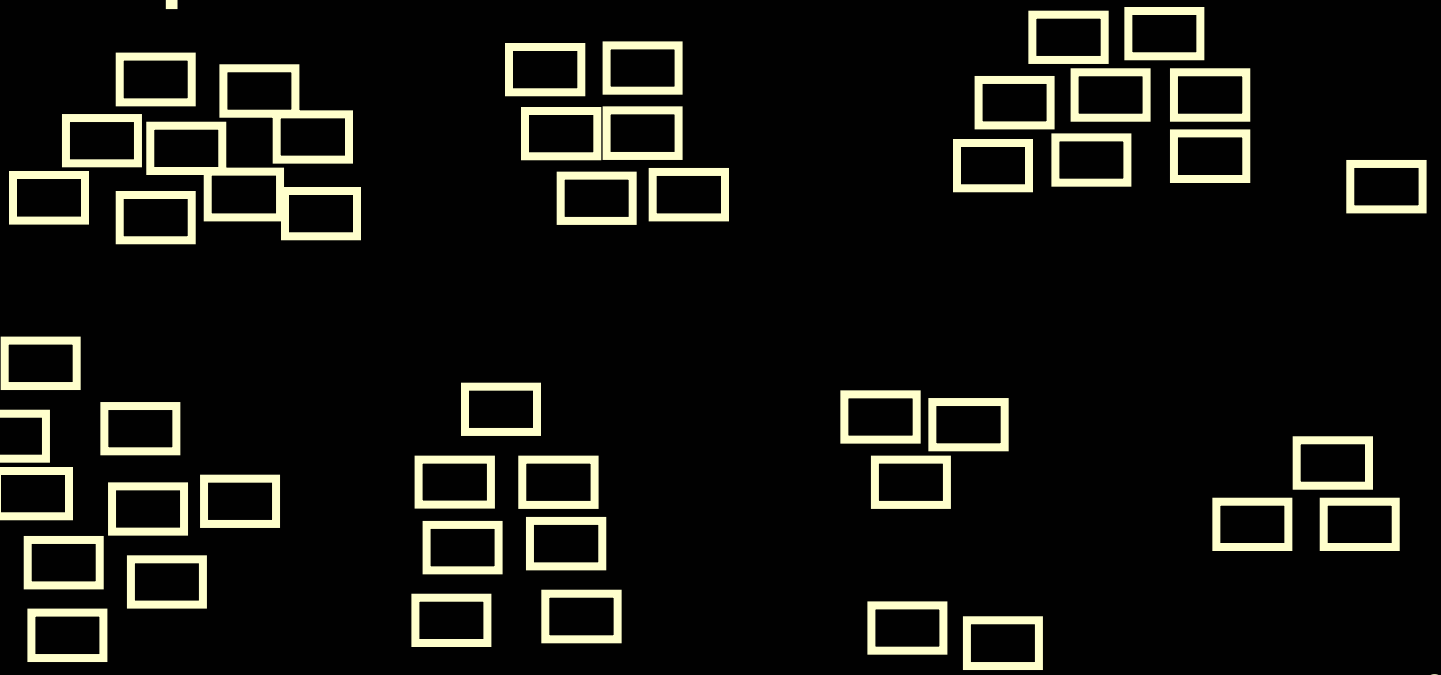
Affinity Mapping

- Use complete sentence to state issue
- Record one idea per card (short phrase with verb)
- Place randomly



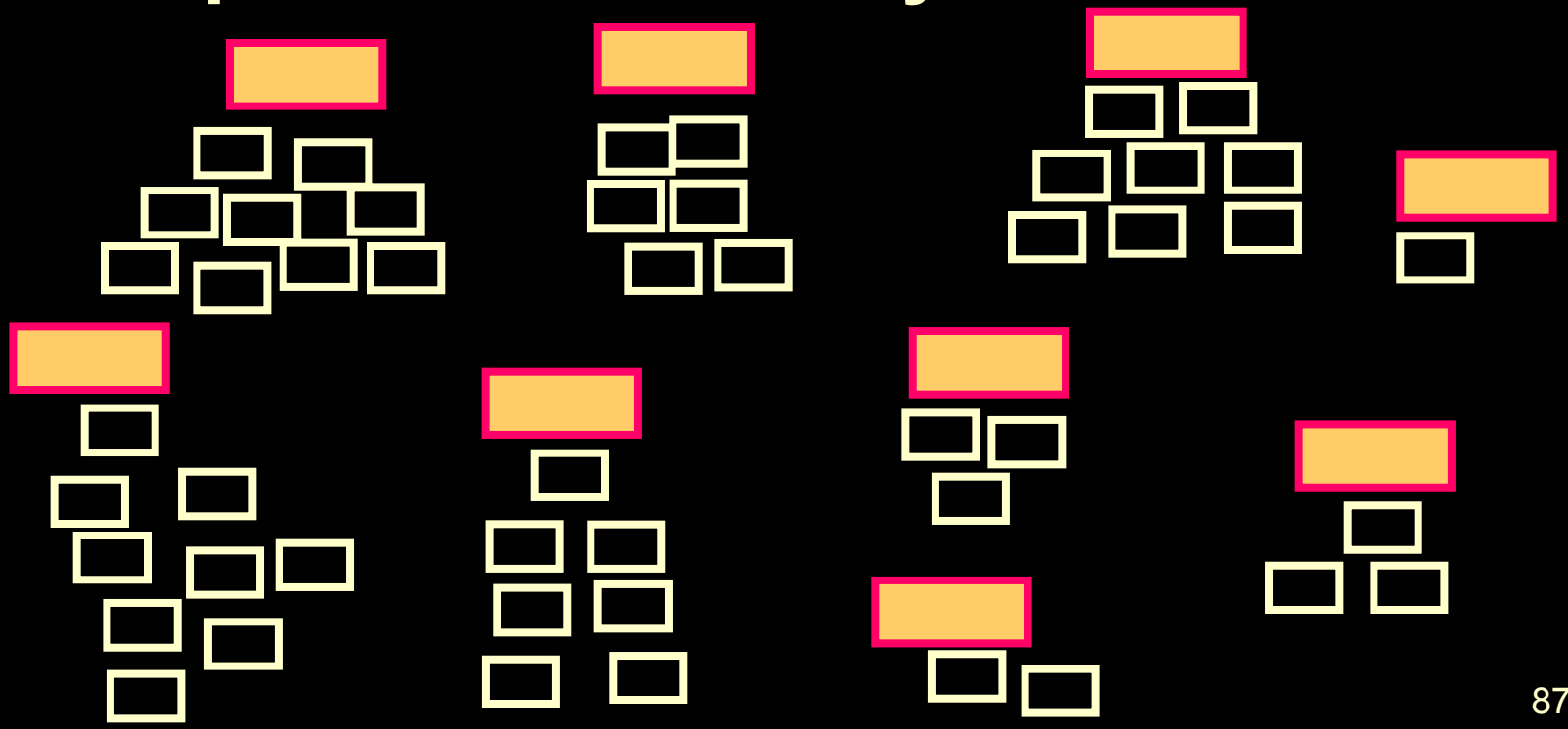
Affinity Mapping

- Don't talk
- Use “other” hand
- Group similar ideas



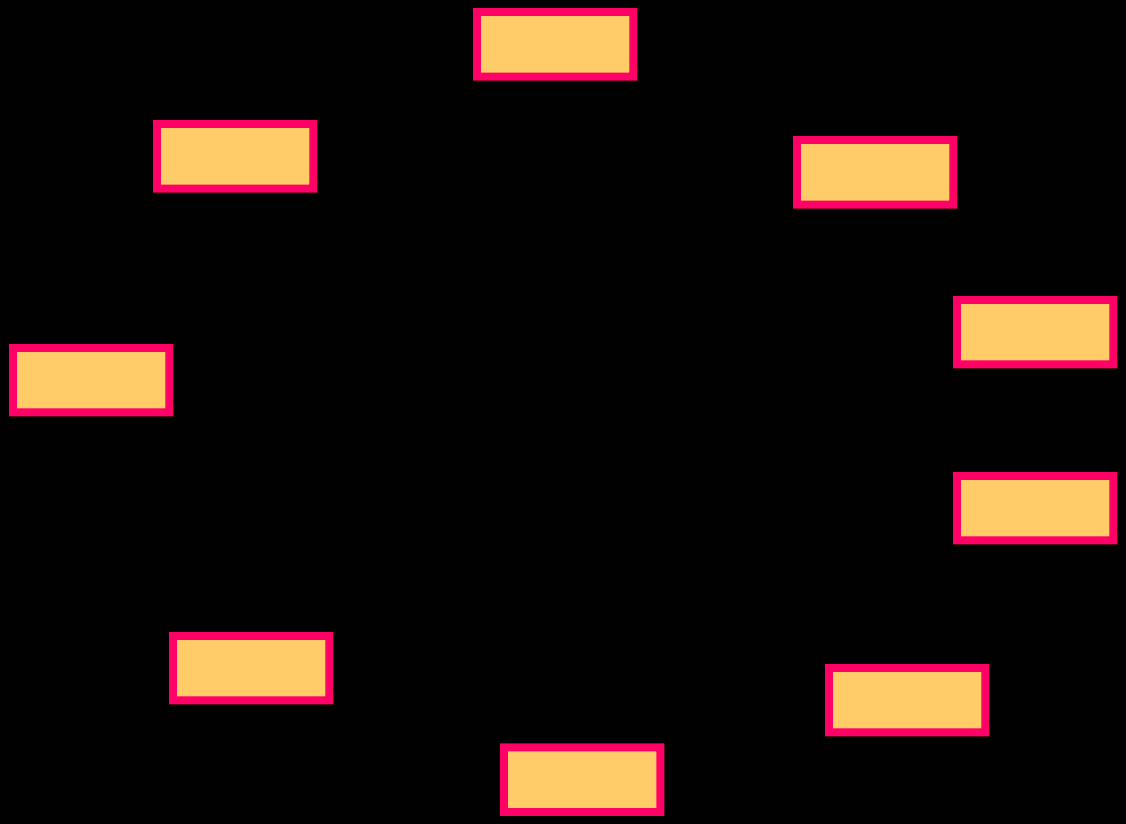
Affinity Mapping

- Name clusters
- Capture commonality of elements



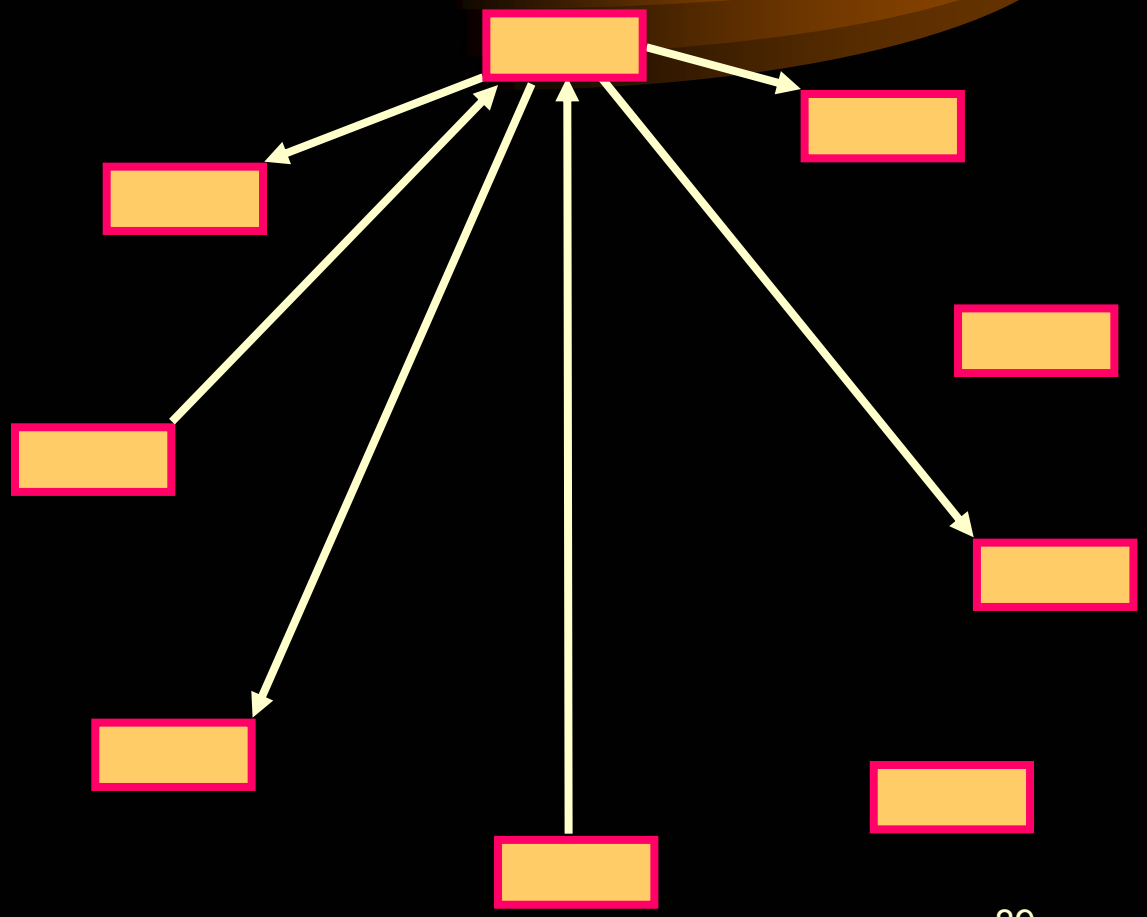
Interrelationship Digraph

- **Place Headers in Circle**



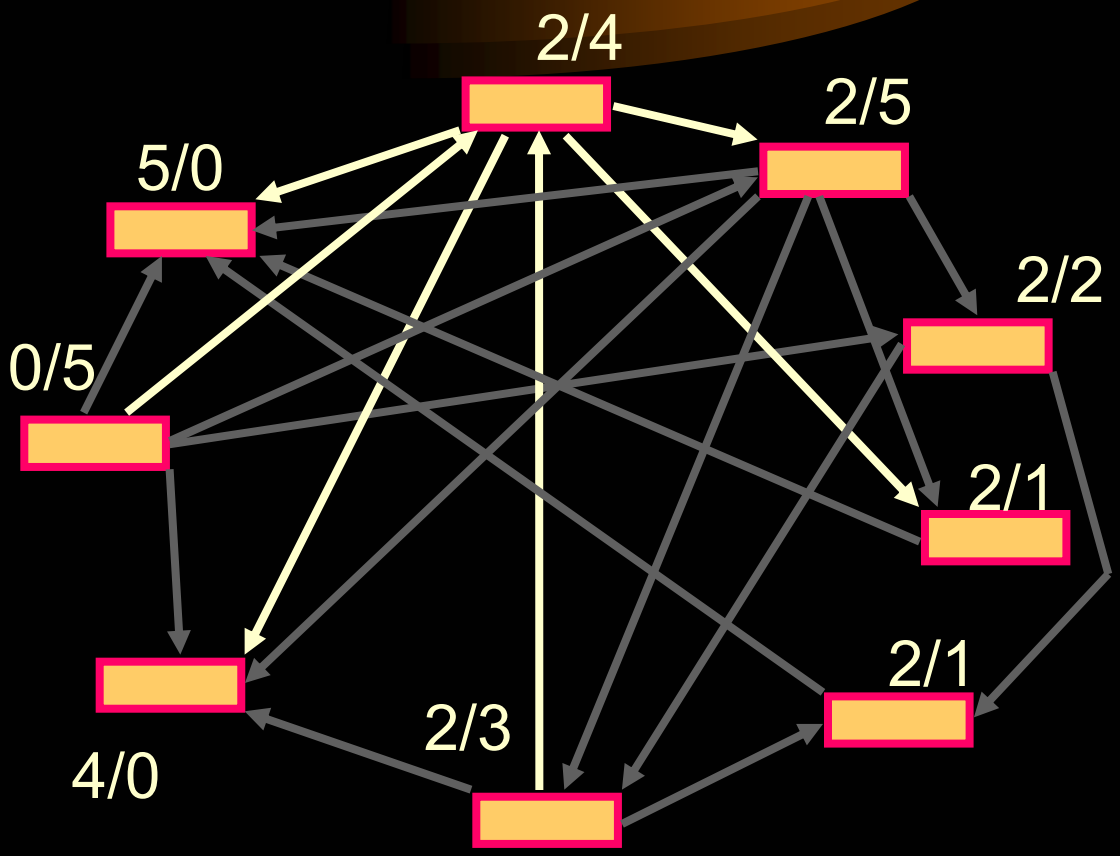
Interrelationship Digraph

- One Header at a Time
- Arrows Indicate Primary Cause
- Arrows One Way Only
- May Have No Arrow



Interrelationship Digraph

- **Complete the Circle**
- **Label "In / Out”**
- **High Number of "Ins" are Effects**
- **High Number of "Outs" are Drivers (Root Causes)**

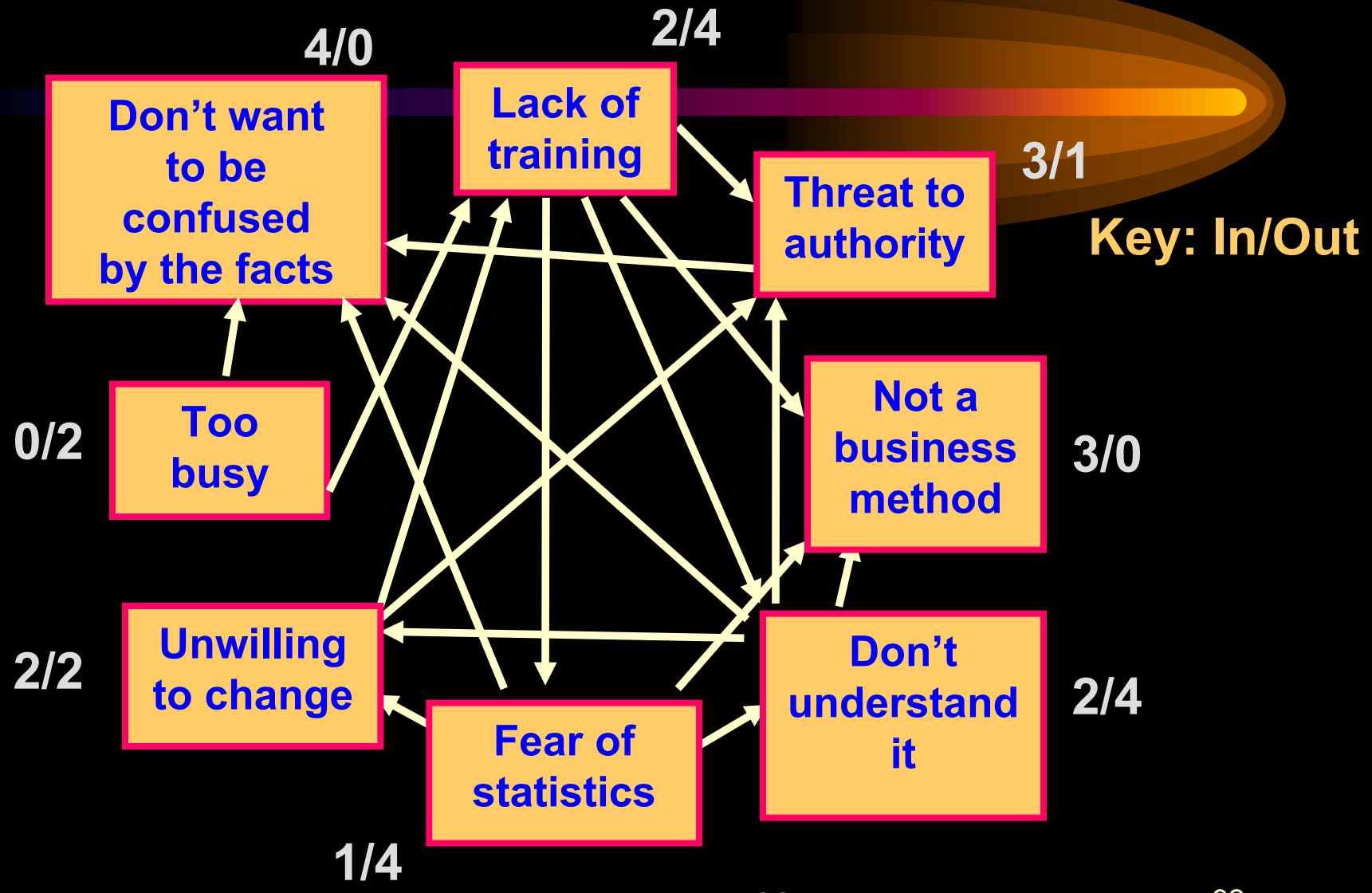


Barriers to Statistical Thinking

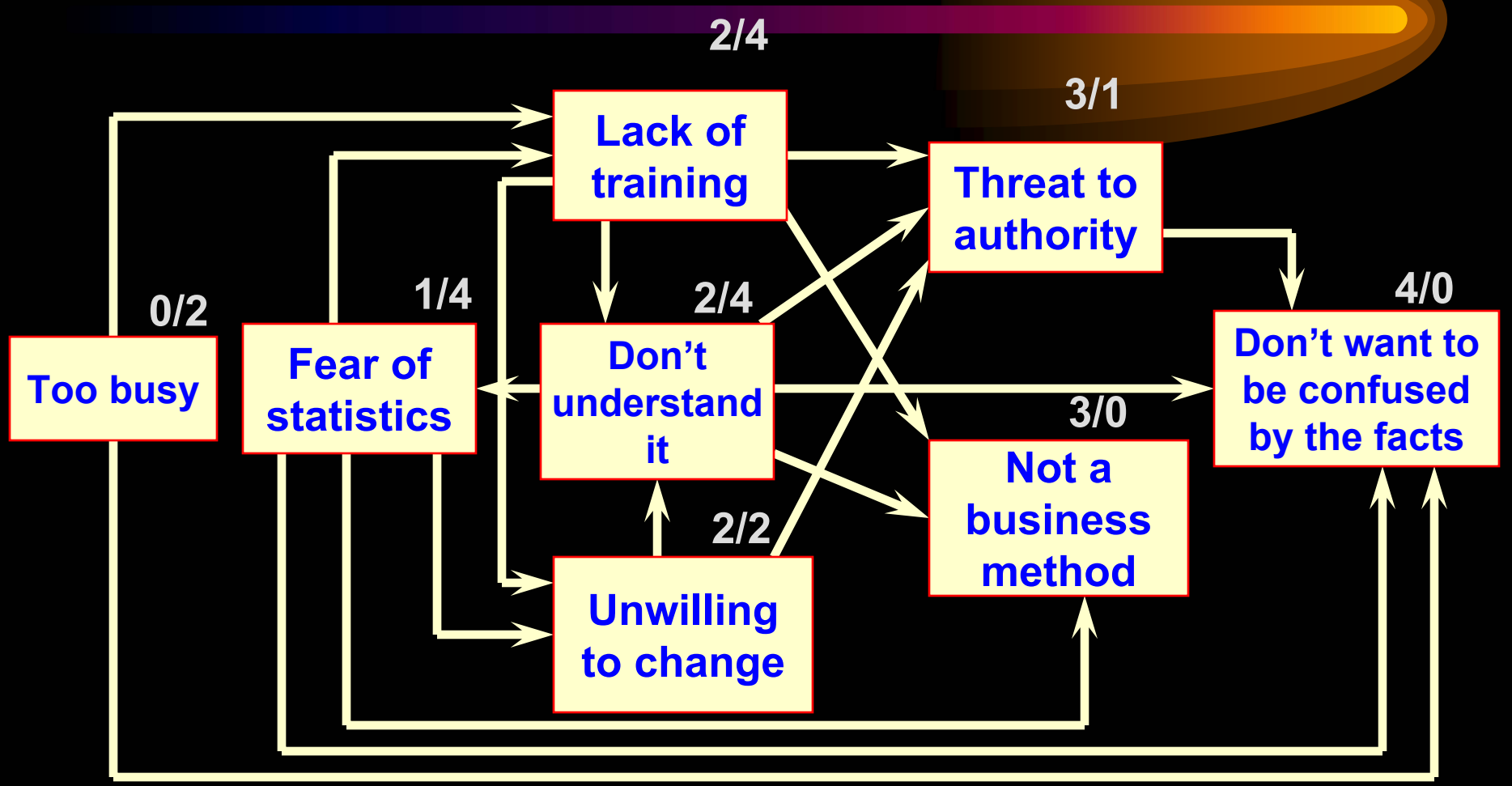
- Lack of training
- Threat to authority
- Not a business method
- Don't understand it
- Fear of statistics
- Unwilling to change
- Too busy
- Don't want to be confused by the facts

49th AQC, 5/23/95

Barriers to Statistical Thinking



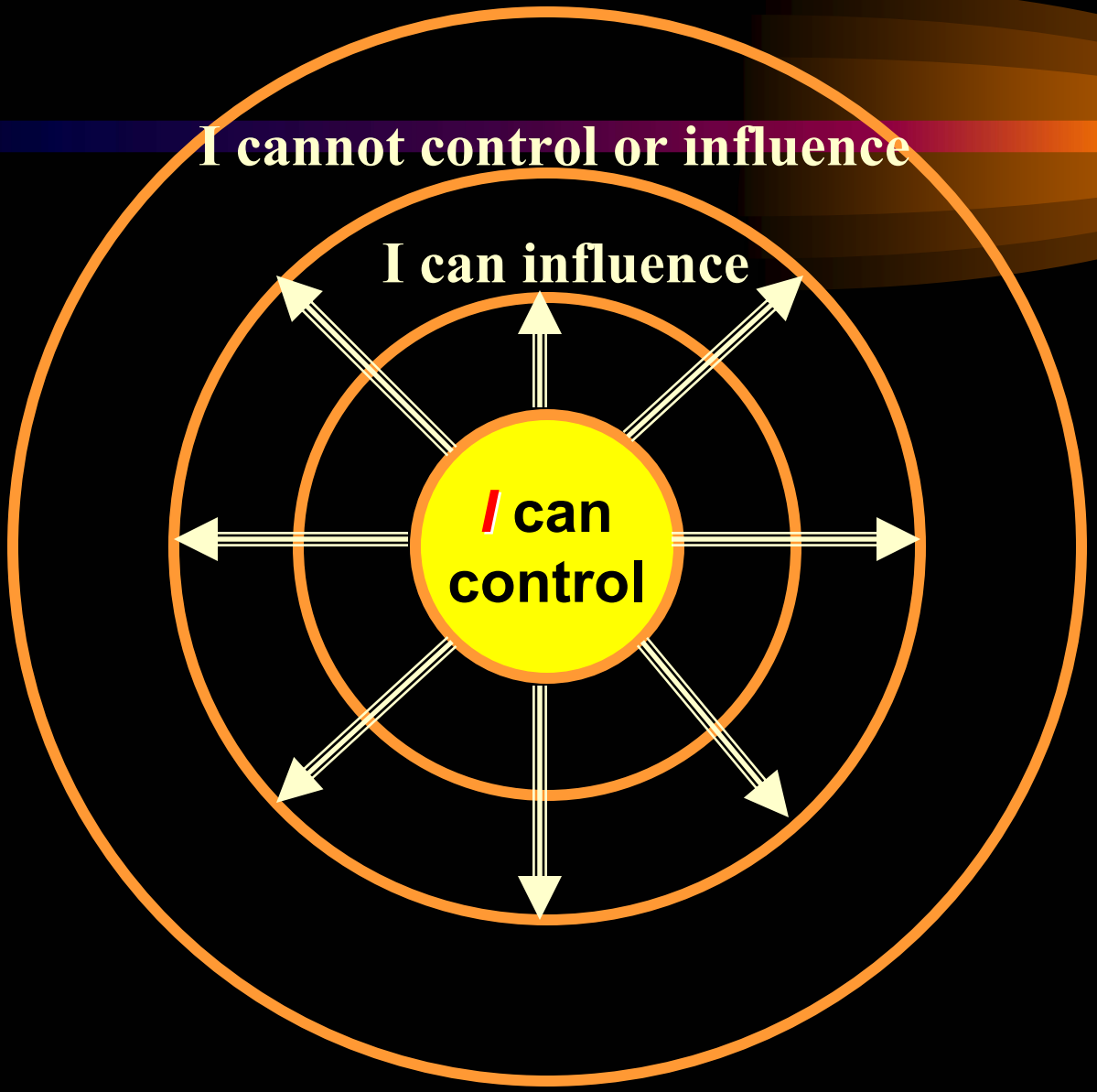
Barriers to Statistical Thinking




Bob Mitchell
3M

Sphere of Influence

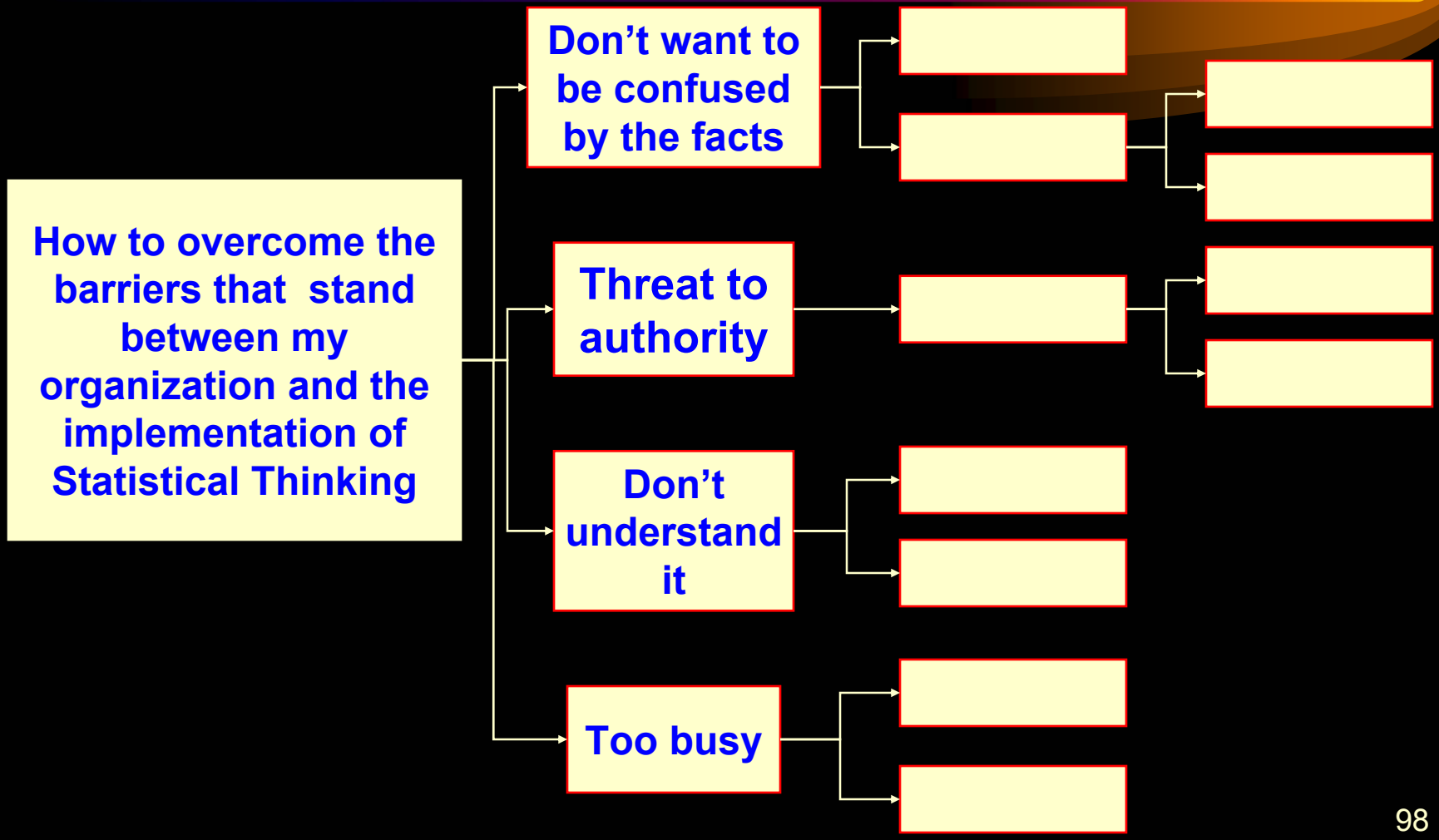
Sphere of Influence



Expanding Your Sphere of Influence

- Find a champion
- Join important teams
- Develop statistically-based management systems
  - Product quality management
  - Strategy of experimentation
  - Process management
- Circulate information on other companies
  - e.g., Six sigma
- Inspire executives to action
  - Perform actionable customer surveys
  - Identify root cause of customer complaints

Tree Diagram

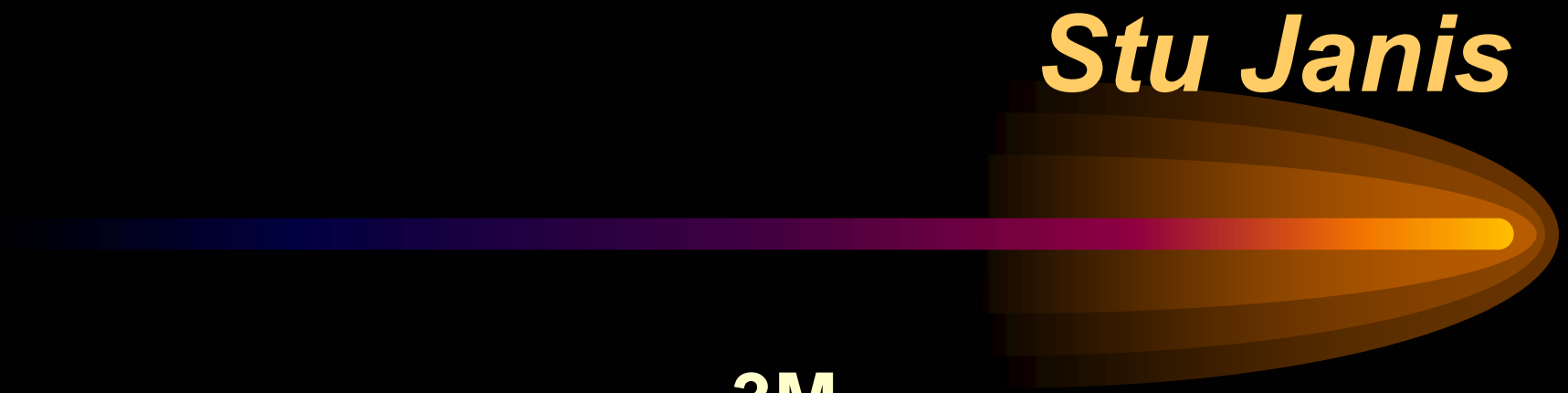


Breakout Assignment

Brainstorm ideas for addressing major barriers to implementing Statistical Thinking. Come to agreement on best ideas.

Group Discussions: (30 Min.)

Reports: (15 Min. each)


Stu Janis
3M

Individual Breakout

- Develop a personal implementation plan to improve the quantity and quality of statistical thinking applications in your organization
- Focus on the “sphere of influence”
- Consider both long and short term actions
- Remember barriers and potential solutions relevant to your situation (discussed earlier)
- The plan should involve tangible actions, not just broad goals; i.e, “I will schedule a meeting with…” instead of “I will champion the cause of…”

Breakout Format

- Take 45 minutes to work on your plan
- Feel free to ask session leaders or other participants for advice
- Be creative! Use text, diagrams, bullet points, etc
- You may wish to begin with a brief description of your situation, including barriers
- We will ask a few volunteers to report their plans (3-5 minutes each)

Summary

- Process focus provides context and relevancy for statistical methods
- Statistical Thinking results in broader, more effective use of statistical methods
  - All parts of the organization
  - Manage and improve processes
  - Guide strategic and managerial action

Feedback for Improvement

Did well	Could do better