LEAN SIX SIGMA FOR CONTINUAL IMPROVEMENT

-- When it's Six Sigma and When it's Lean

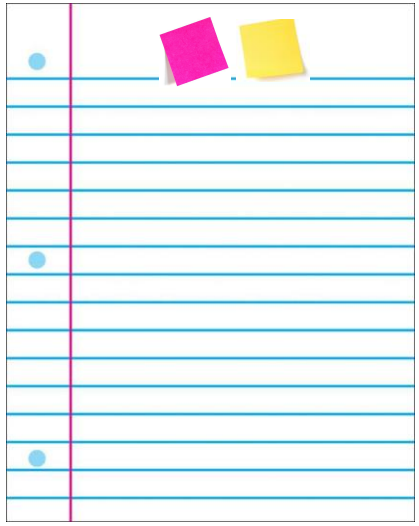
20 September 2019

Steve Zagarola
szagarola@nwcpe.com
(770) 365 3427

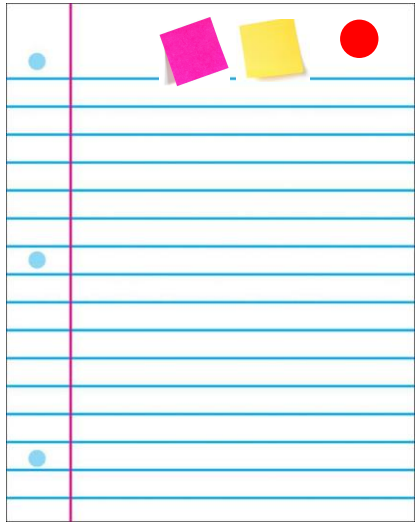
NWCPE; 25 NW 23rd PL. Suite 6 PMB 381
Portland, OR 97210

NWCPE

- Notebook w/2 post-it notes -- some with a dot.
- Share a post-it note with your neighbor if they don't have a notebook.
- Write your name on one post-it note.

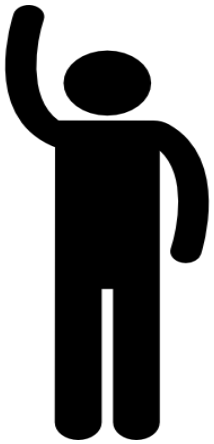


or

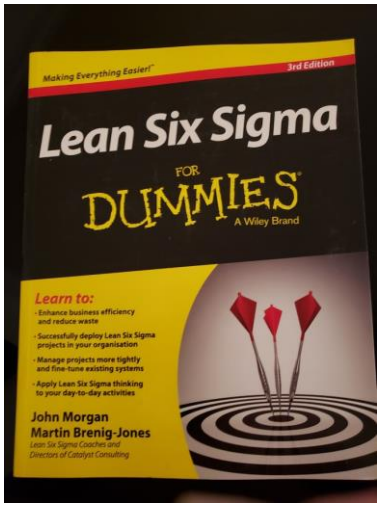


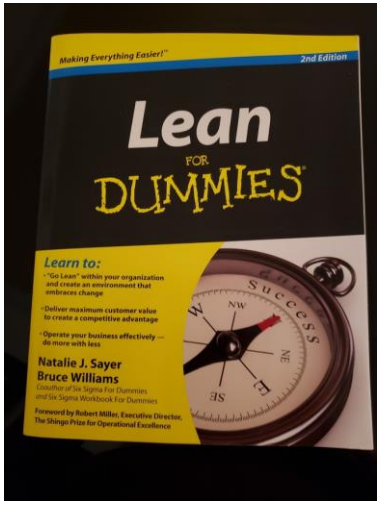
BOOK GIVEAWAY - RAISE YOU HAND (or have a dot) TO QUALIFY

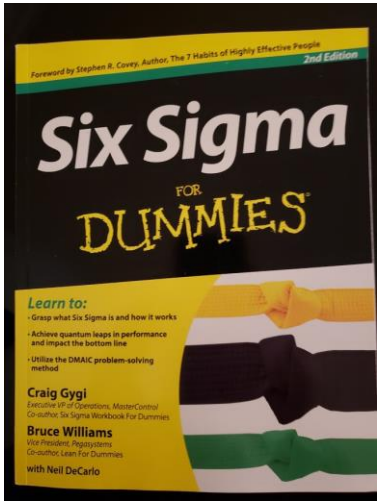
- Name
- Favorite music
- Favorite vegetable
- Your answer



OR







- LSS AND PROCESS EXCELLENCE
- CENTRAL THEMES & METHODS
- COMPETE OR COMPLEMENT?
- CONCLUSIONS

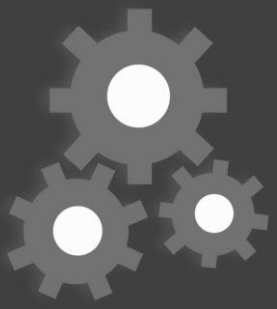
LSS AND PROCESS EXCELLENCE

LEAN SIX SIGMA

PROCESS EXCELLENCE

SYSTEMATIC PROCESS DESIGN

CONTINUAL IMPROVEMENT

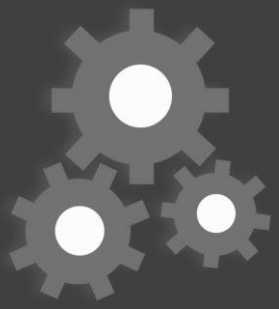


PROCESS

EXCELLENCE

CUSTOMER

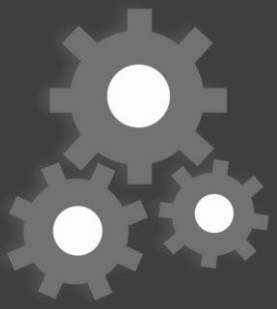
CENTRIC



PROCESS

EXCELLENCE

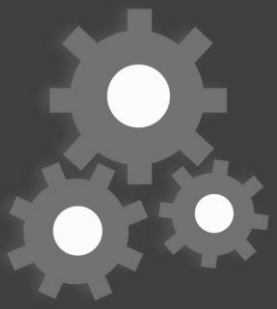
ALIGNED WITH VISION



PROCESS

EXCELLENCE

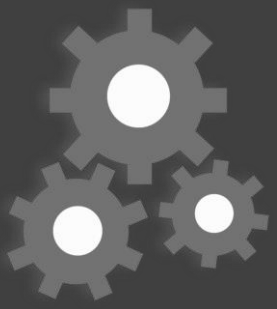
TARGETED



PROCESS

EXCELLENCE

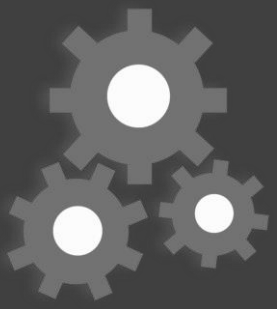
CONSISTENT



PROCESS

EXCELLENCE

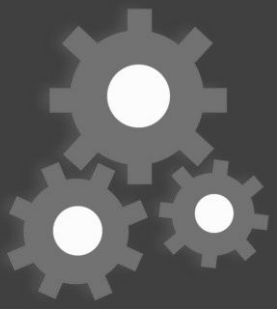
PRODUCTIVE



PROCESS

EXCELLENCE

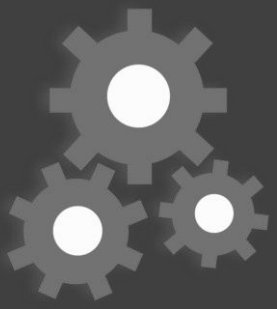
TIMELY



PROCESS

EXCELLENCE

INSIGHTFUL



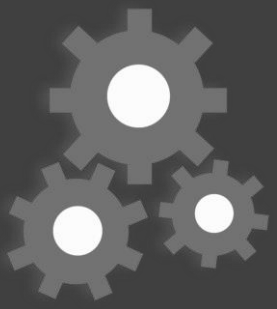
PROCESS

EXCELLENCE

CONTINUALLY

SYSTEMATICALLY

IMPROVING



PROCESS EXCELLENCE

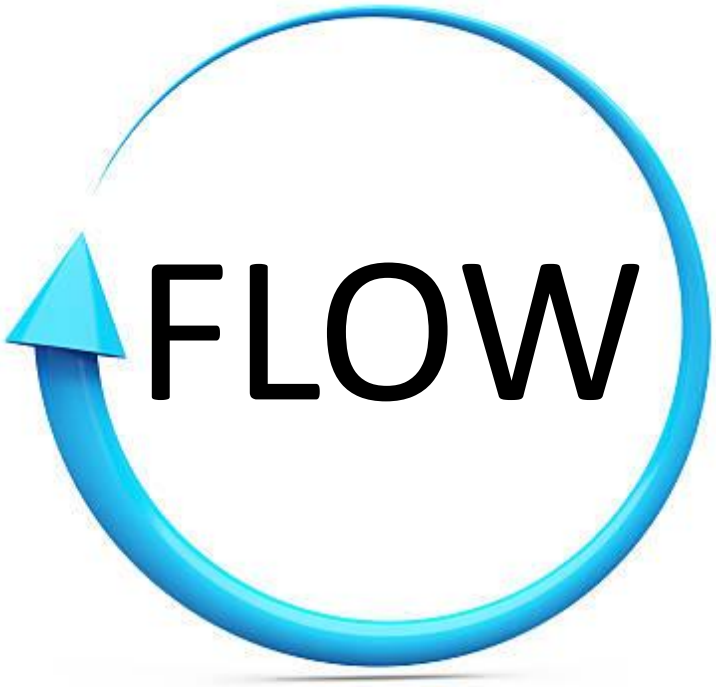
- CUSTOMER
- VISION
- TARGETED
- CONSISTENT
- PRODUCTIVE
- TIMELY
- INSIGHTFUL
- CONTINUALLY IMPROVING

LEAN - CENTRAL THEMES

LEAN --

CENTRAL

THEMES



LEAN --

CENTRAL

THEMES

LEAN --

CENTRAL

THEMES

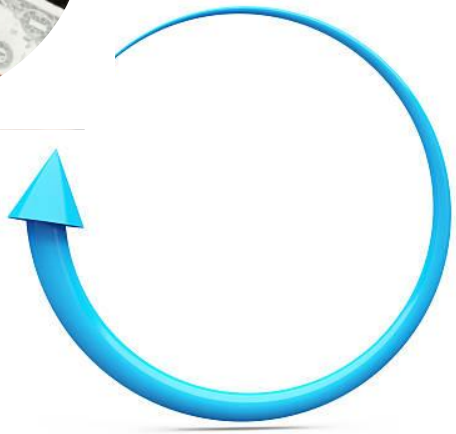
NON-VALUE ADDING ACTIVITIES (NVA)

LEAN -- CENTRAL THEMES

DON’T DIRECTLY TRANSFORM INPUT INTO WHAT THE CUSTOMER VALUES

pan

(bread)



QUESTION 1

NVA

PROCESS

STEPS

Pass down your post-it notes if you raised your hand.

QUESTION 1

NON-VALUE ADDING STEPS?

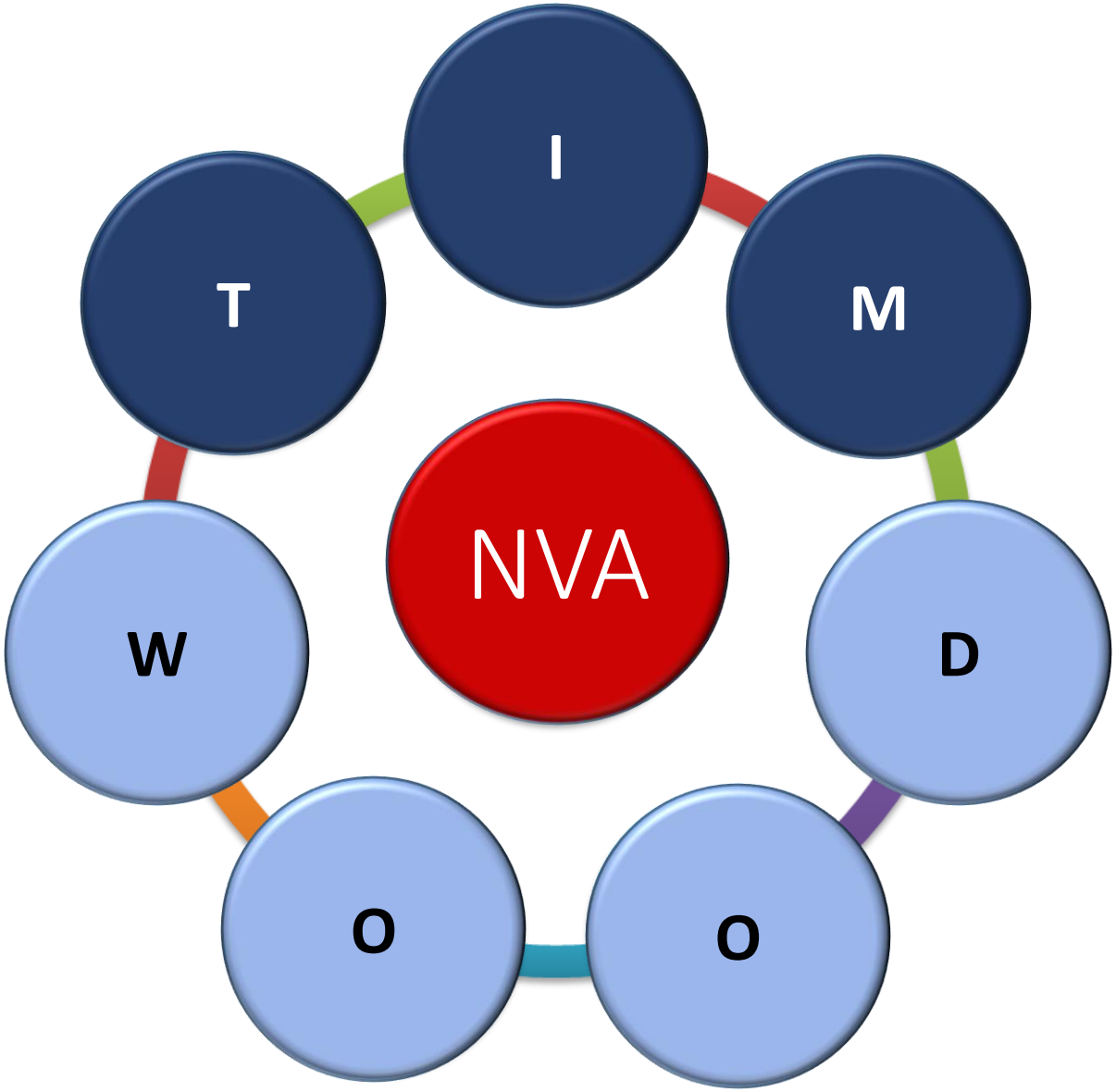
- _____

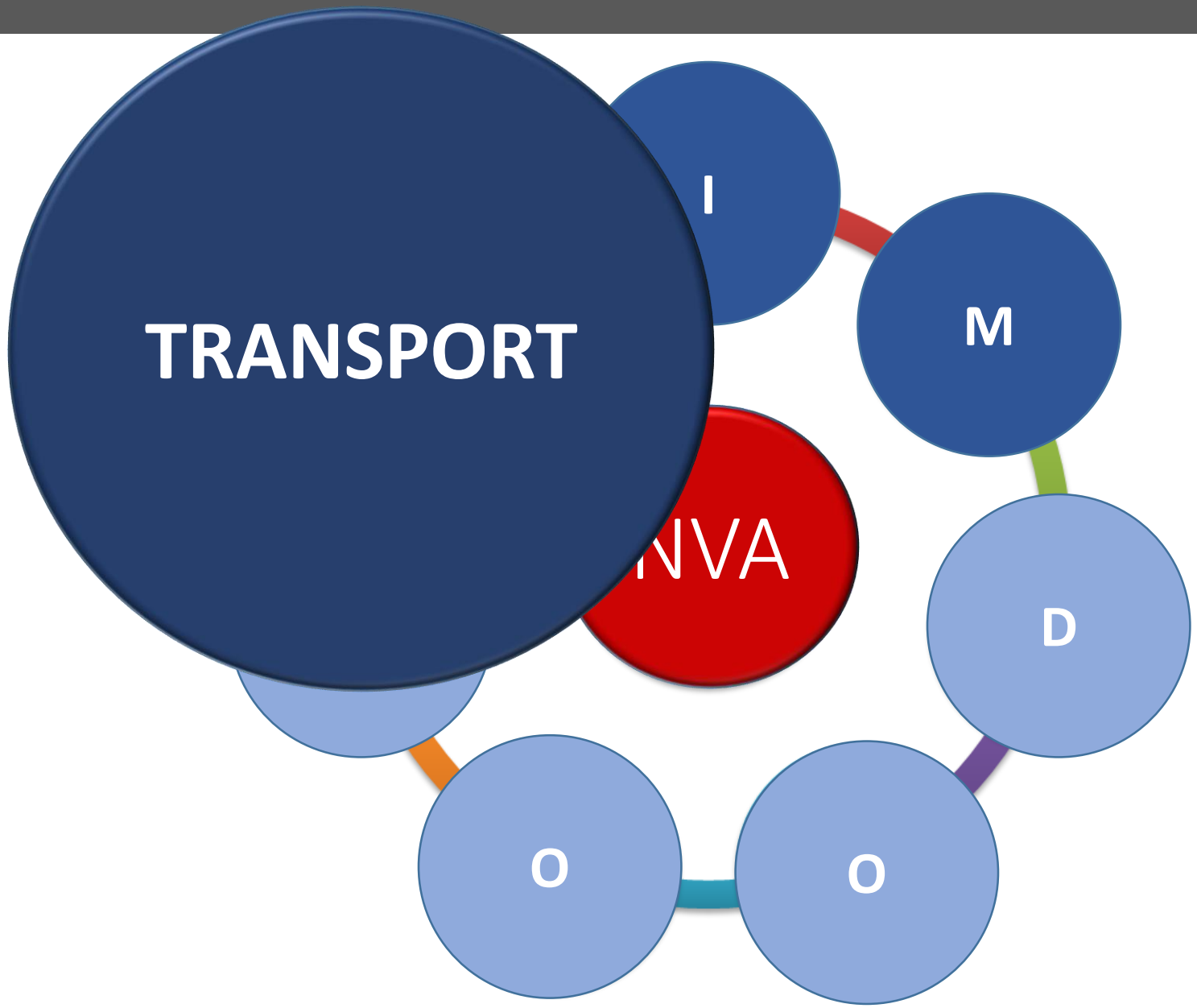
- _____

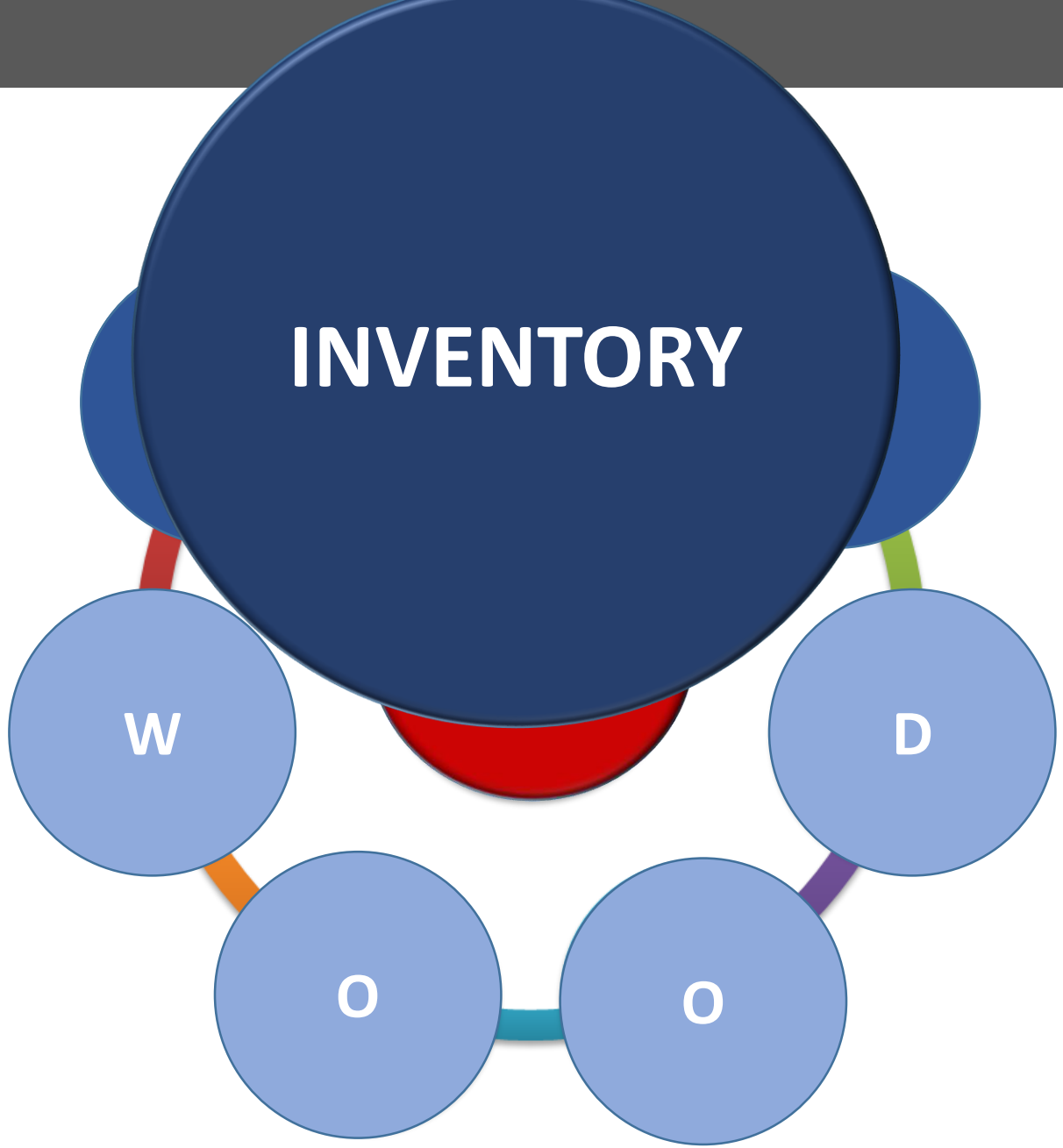
- _____

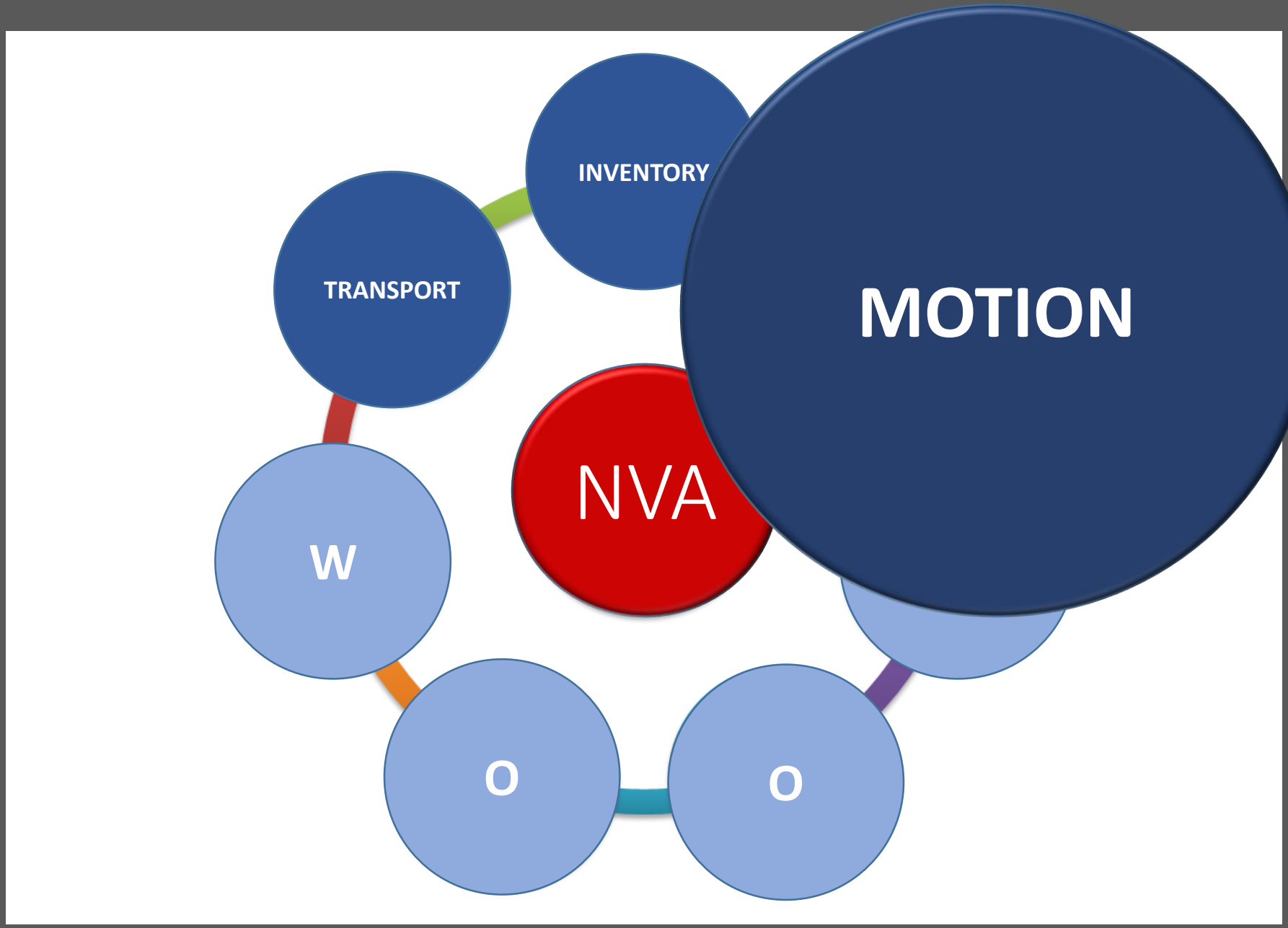
- _____

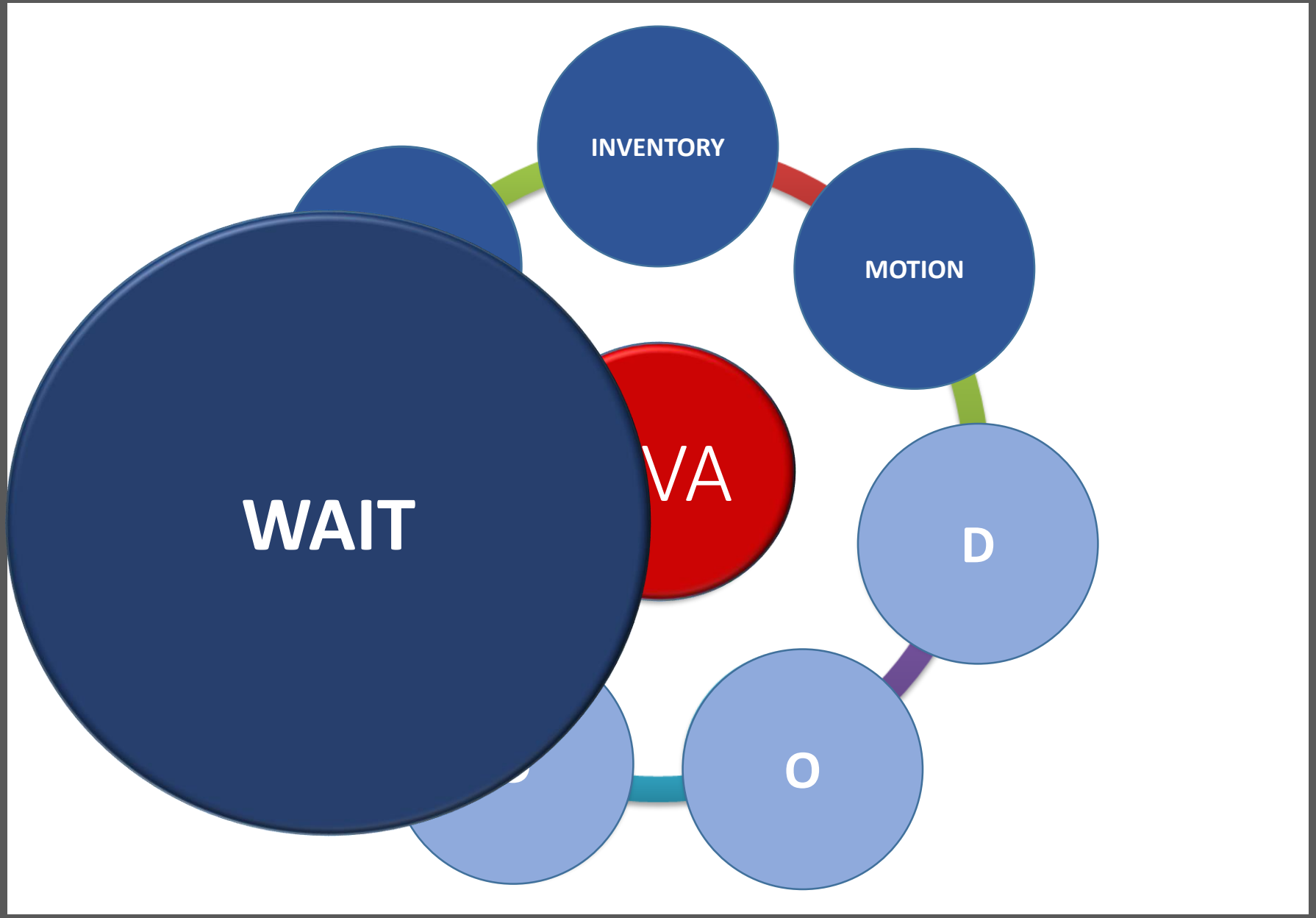
INTRODUCING

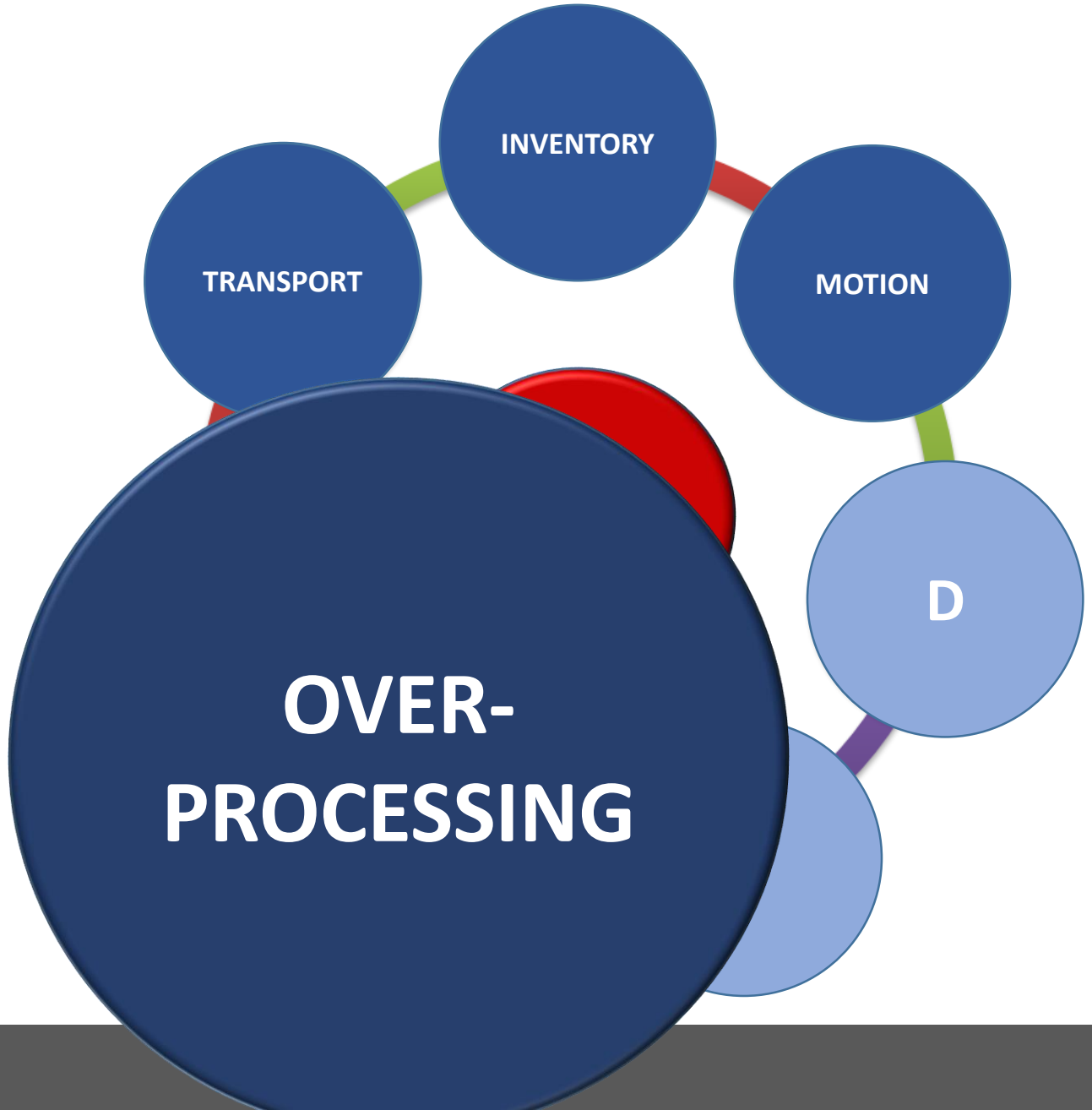

I
M
D
O
O
W
T
NVA

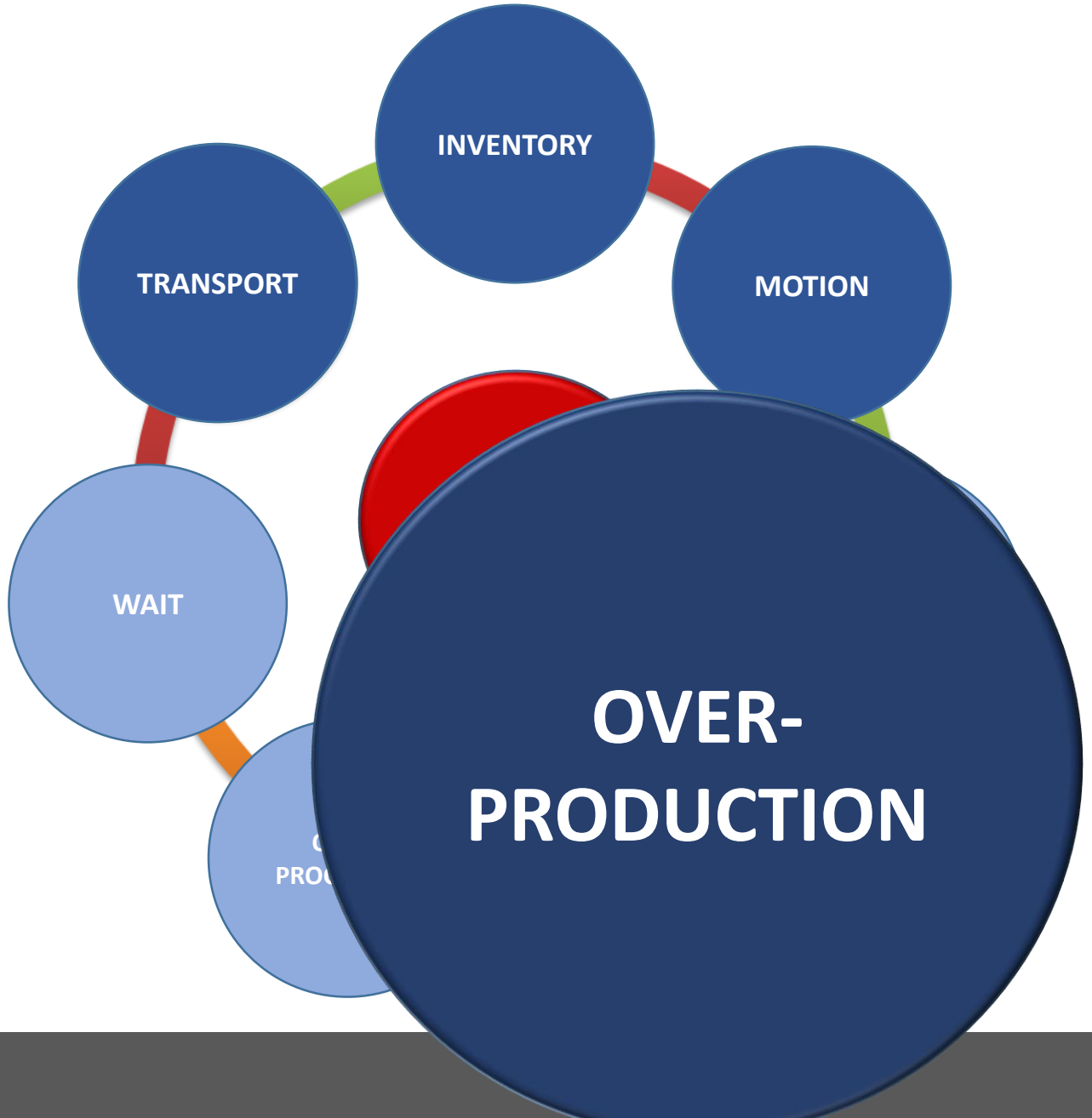

TRANSPORT
I
M
NVA
D
O
O

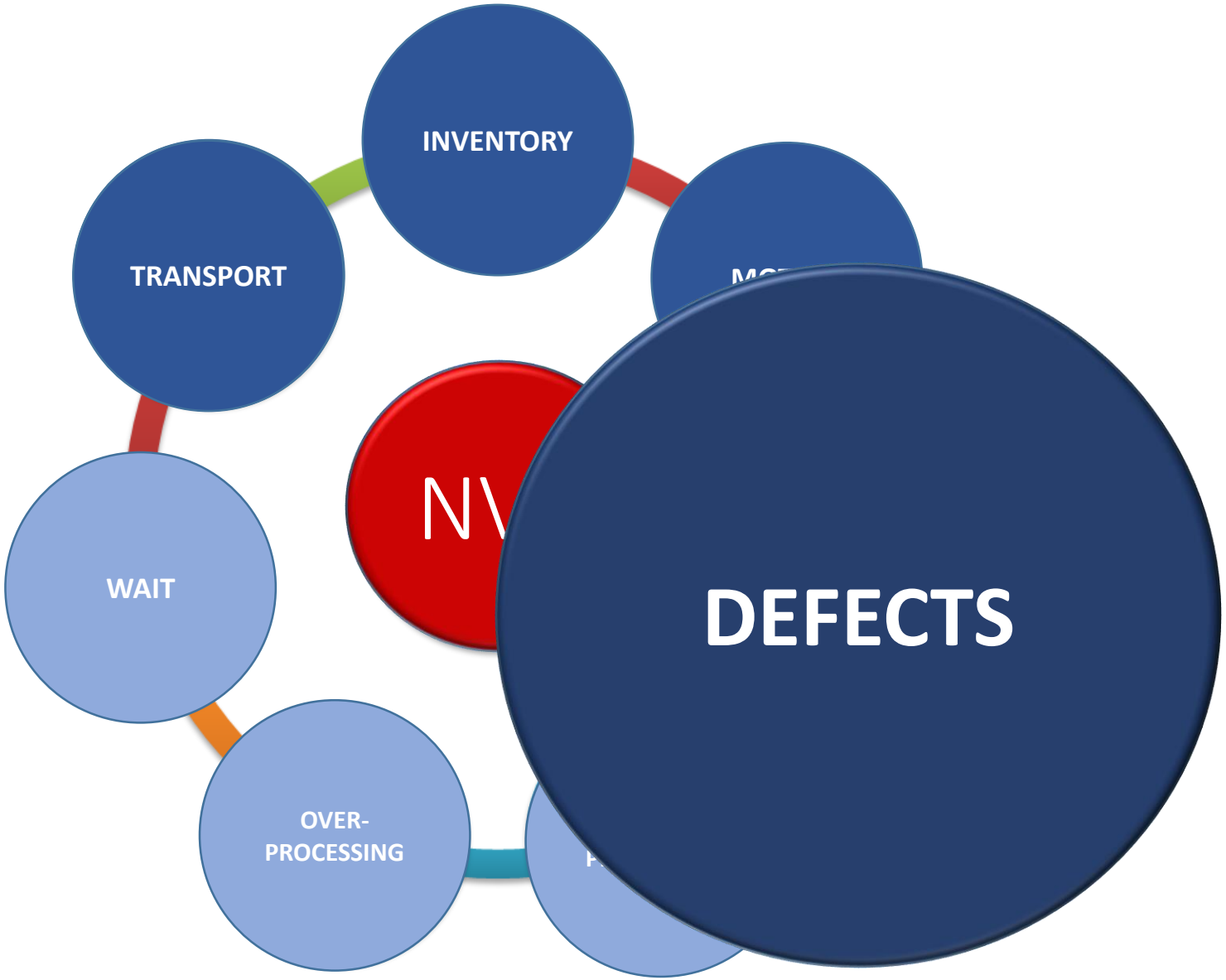

INVENTORY
W
D
O
O

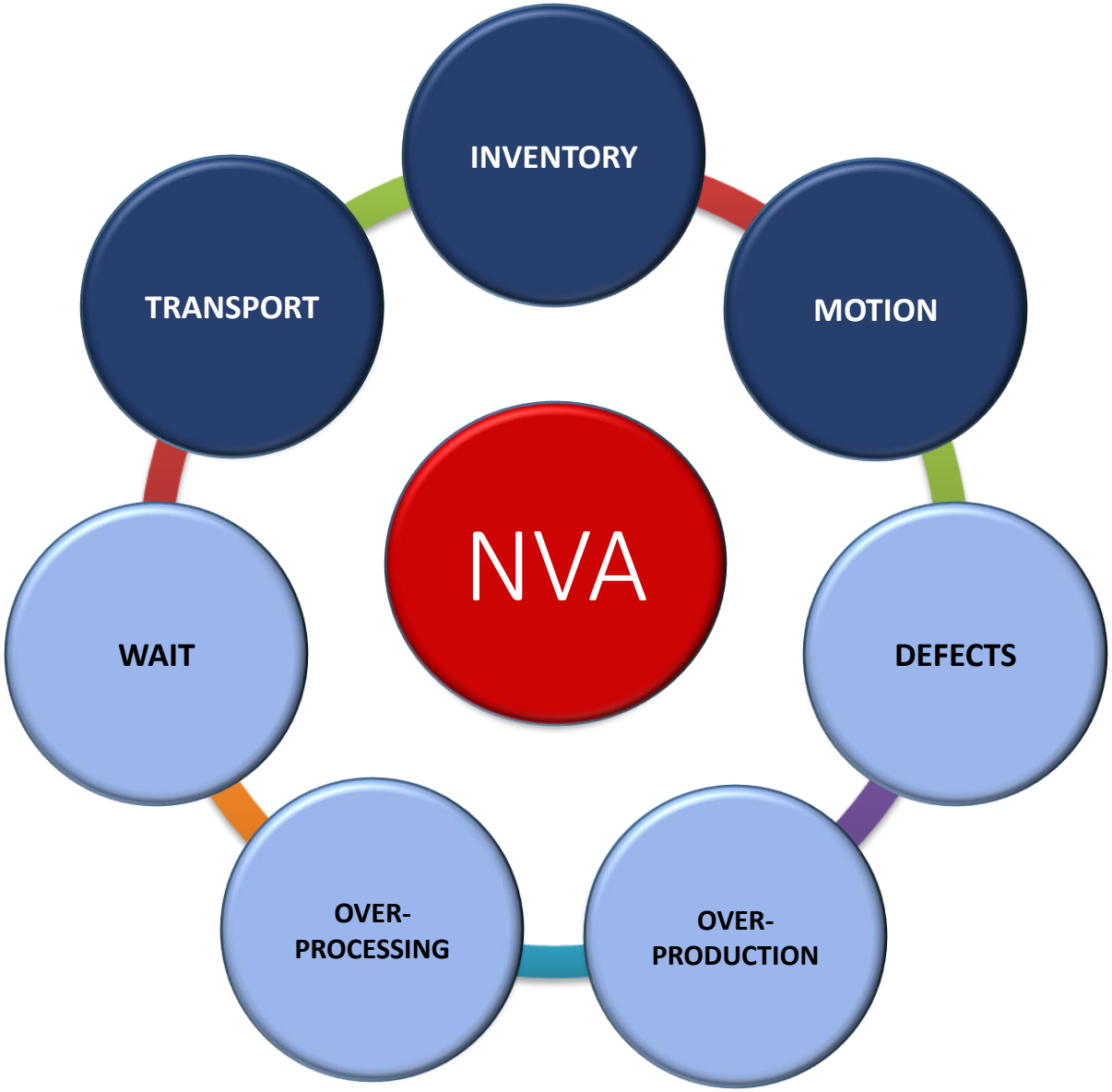

INVENTORY
TRANSPORT
MOTION
NVA
W
O
O


INVENTORY
MOTION
WAIT
VA
D
O


INVENTORY
TRANSPORT
MOTION
D
OVER-
PROCESSING


INVENTORY
TRANSPORT
MOTION
WAIT
OVER-
PRODUCTION

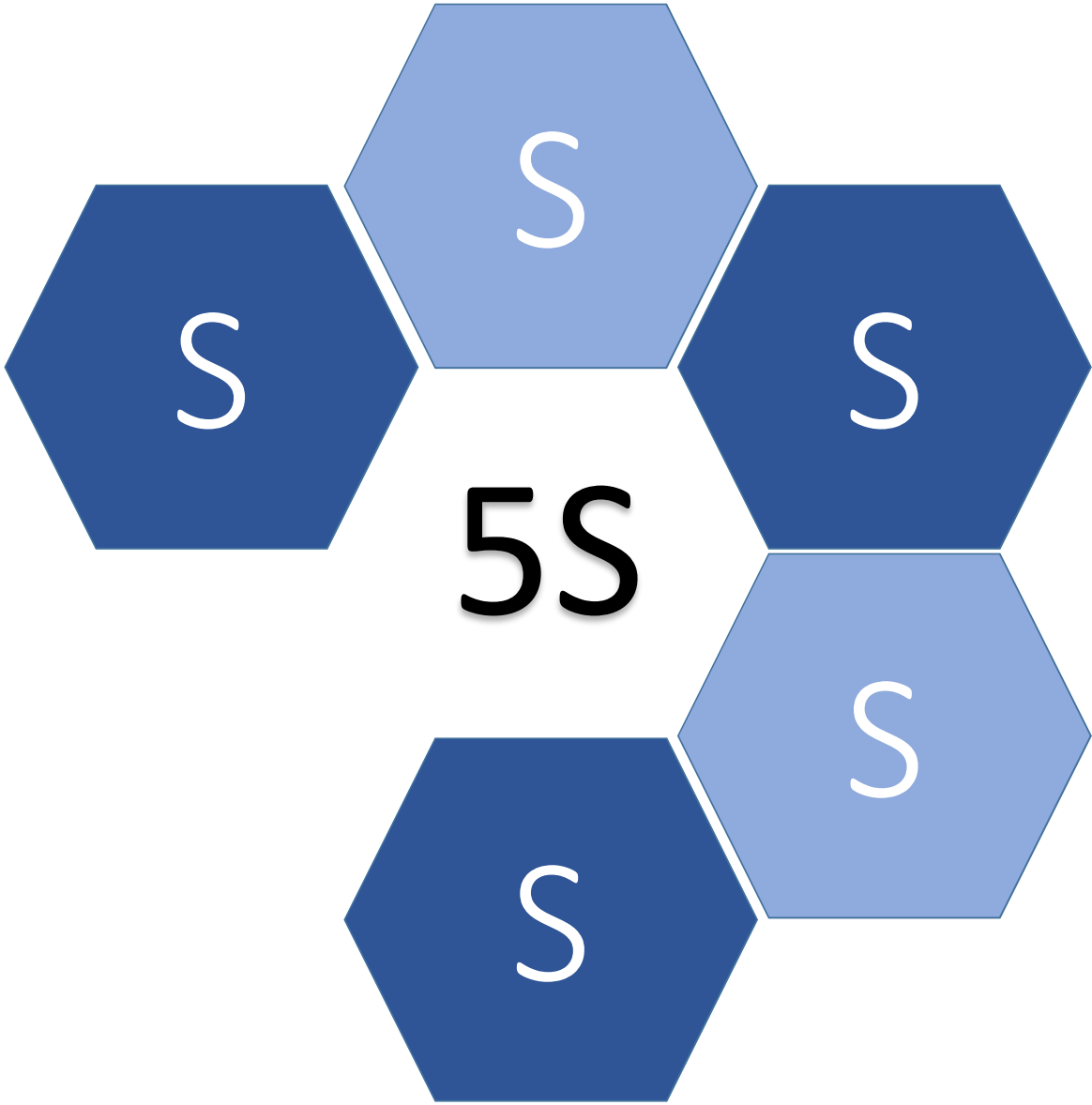

INVENTORY
TRANSPORT
WAIT
OVER-
PROCESSING
DEFECTS


INVENTORY
MOTION
DEFECTS
OVER-
PRODUCTION
OVER-
PROCESSING
WAIT
TRANSPORT
NVA

TIM WOOD(S)

RAPPER

LEAN – METHODS


S
S
S
5S
S
S

5S

- SORT
- SET IN ORDER
- SHINE
- STAND-ARDIZE
- SUSTAIN

QUESTION 2

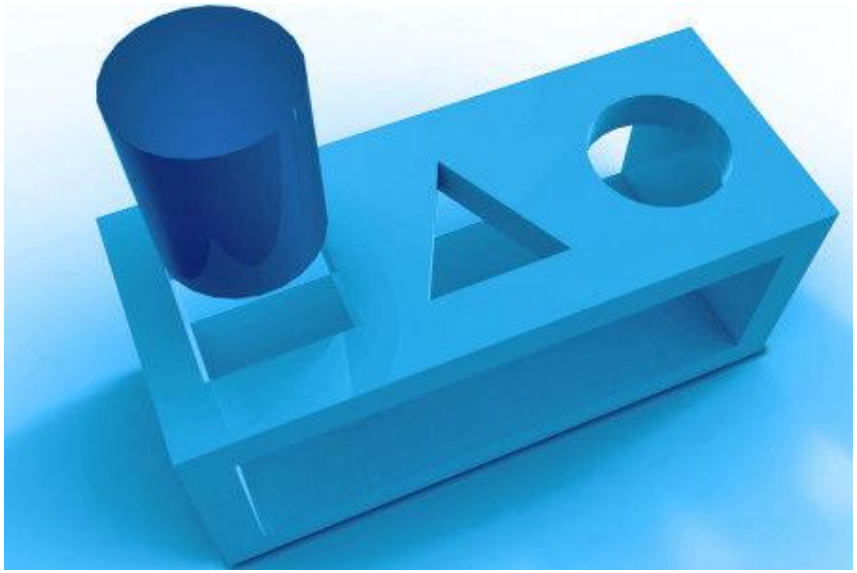
5 S

Pass down your post-it notes if you raised your hand.

WASTE ADDRESSED?

QUESTION 2 – 5S

POKA YOKE



QUESTION 3

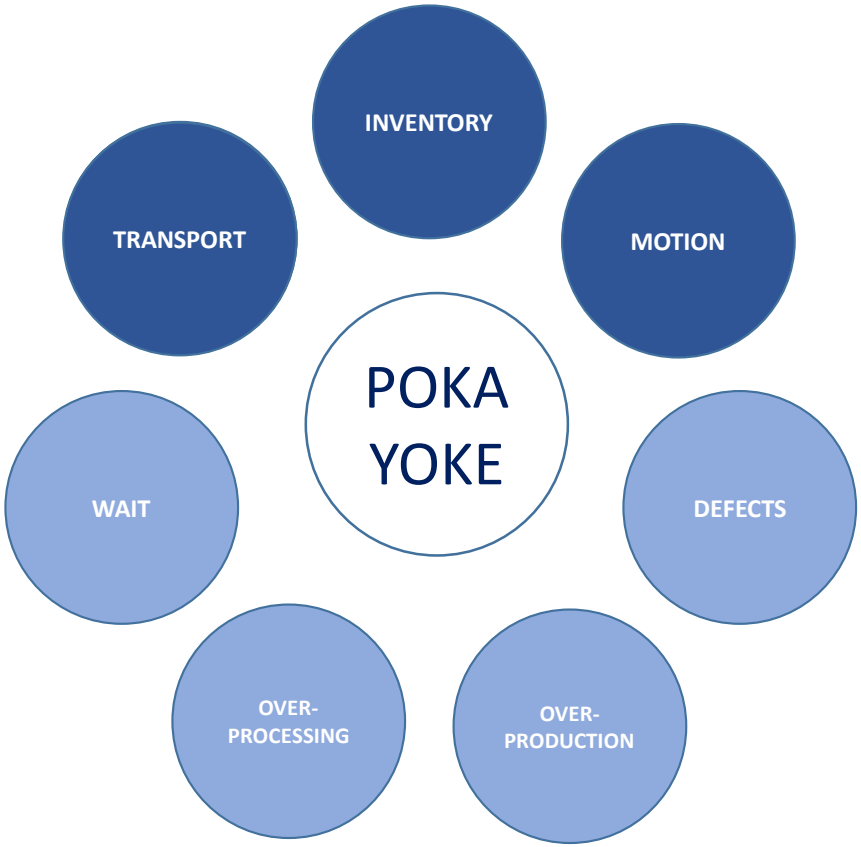
POKA

YOKE

Pass down your post-it notes if you raised your hand.

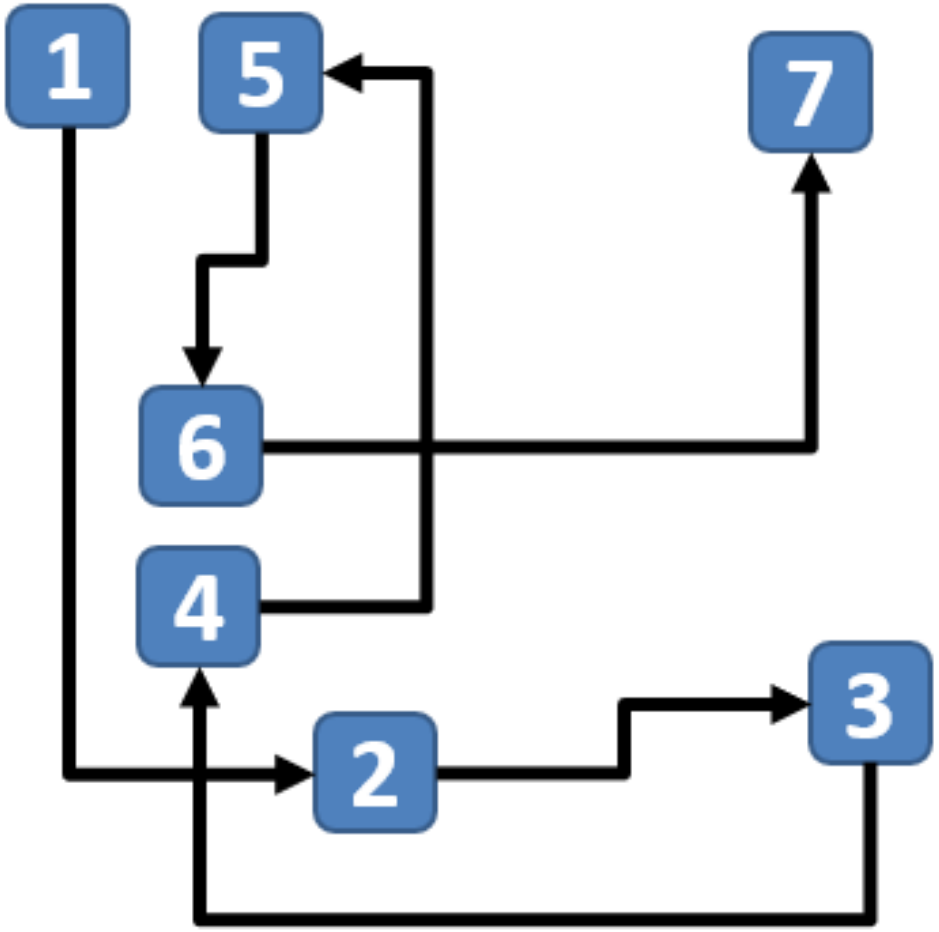
WASTE ADDRESSED?

QUESTION 3 – POKA YOKE



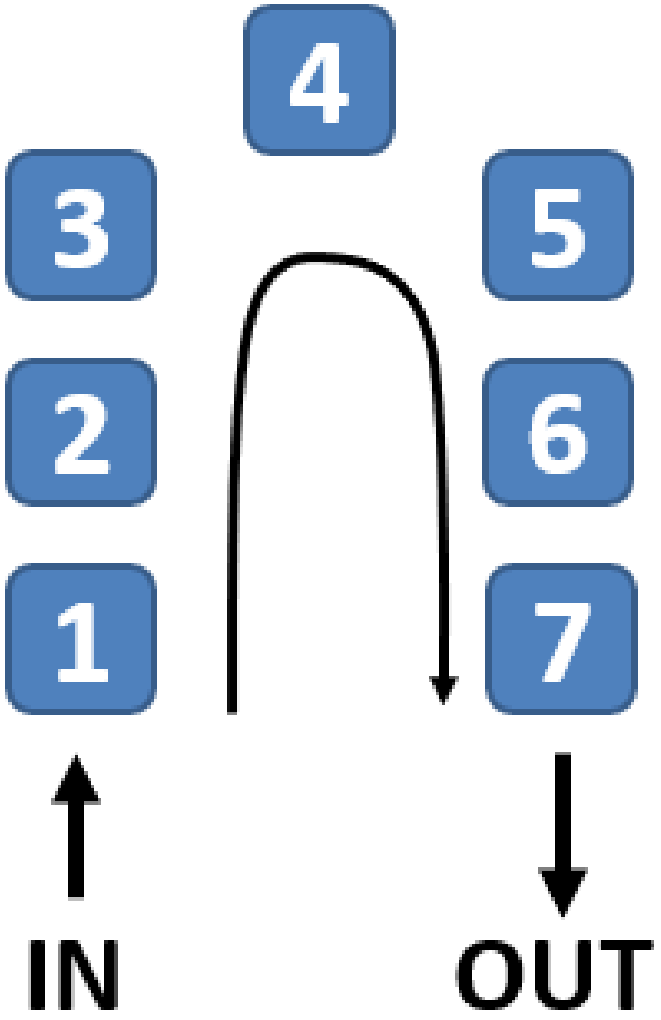
CELL DESIGN

BEFORE



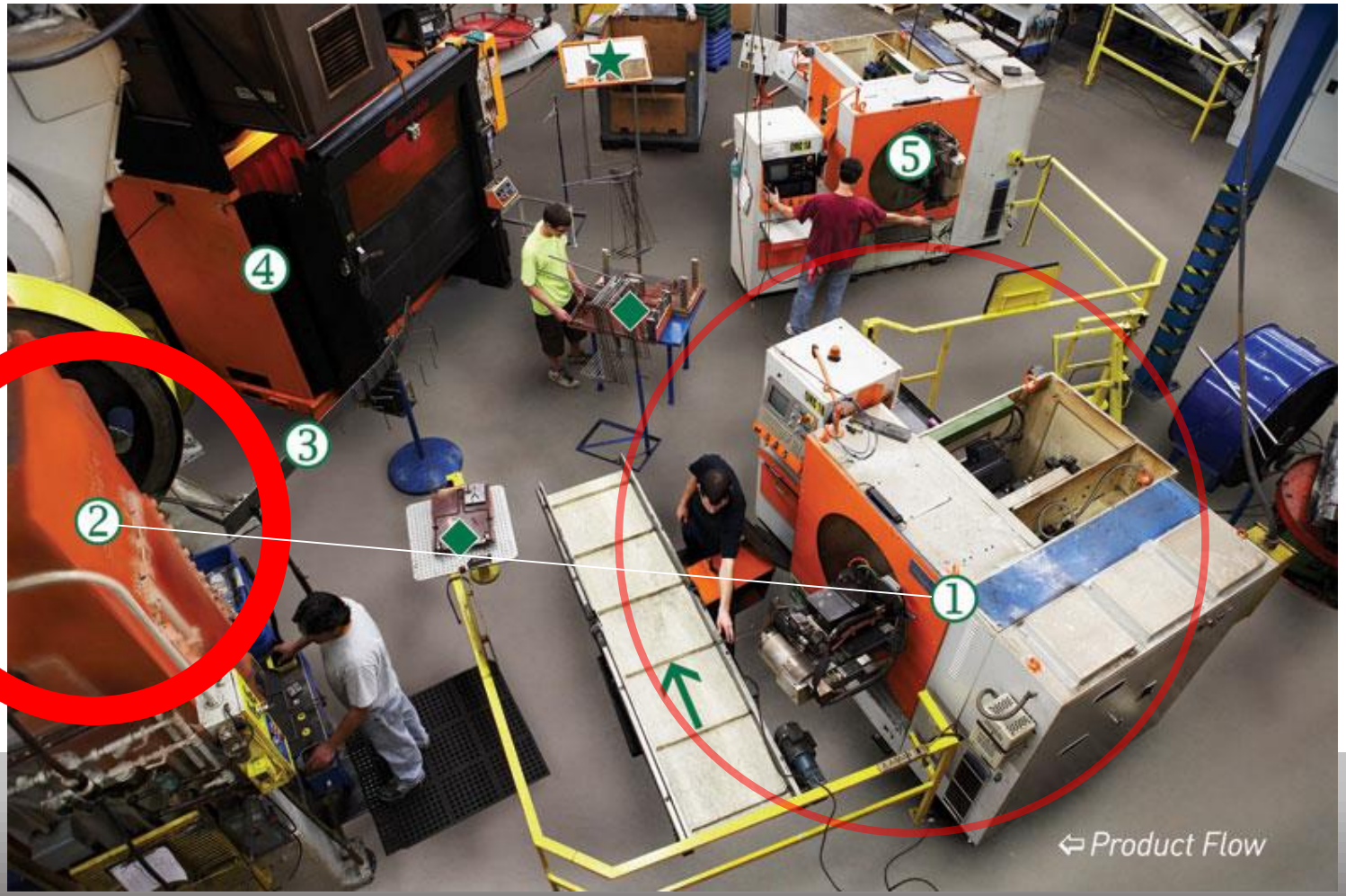
CELL DESIGN

REDESIGN TO FIT THE FLOW

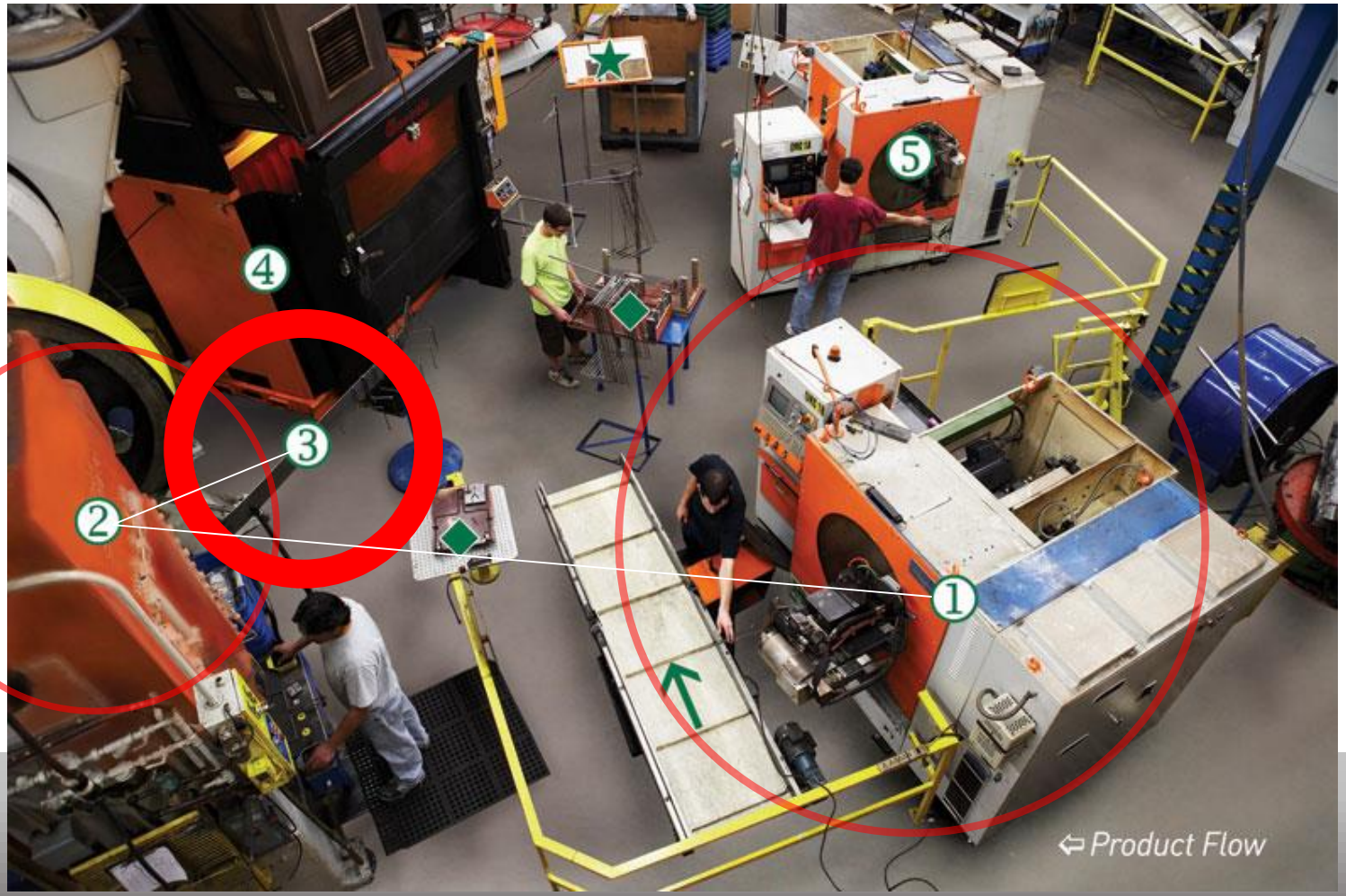


CELL DESIGN

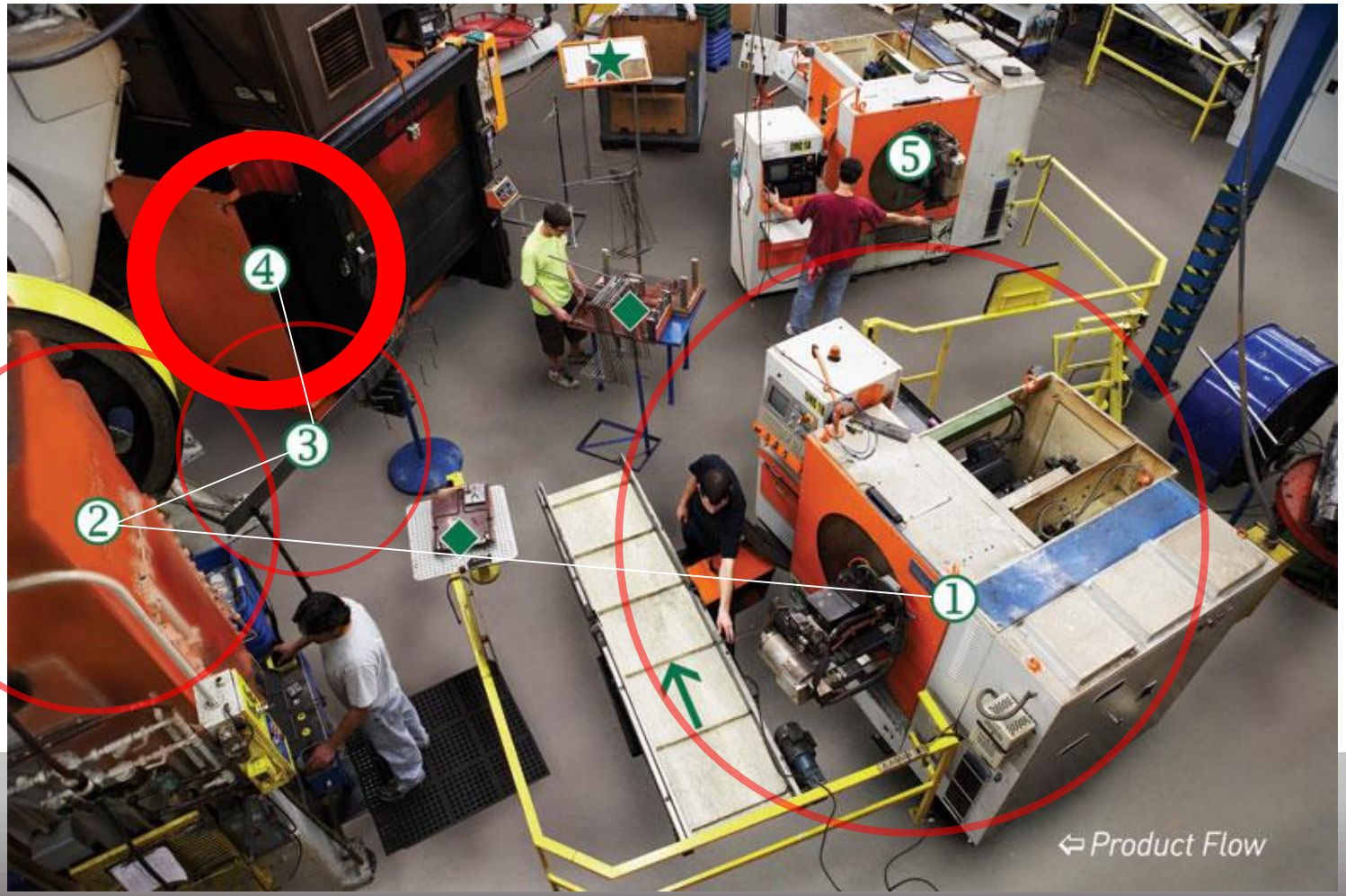
CELL DESIGN



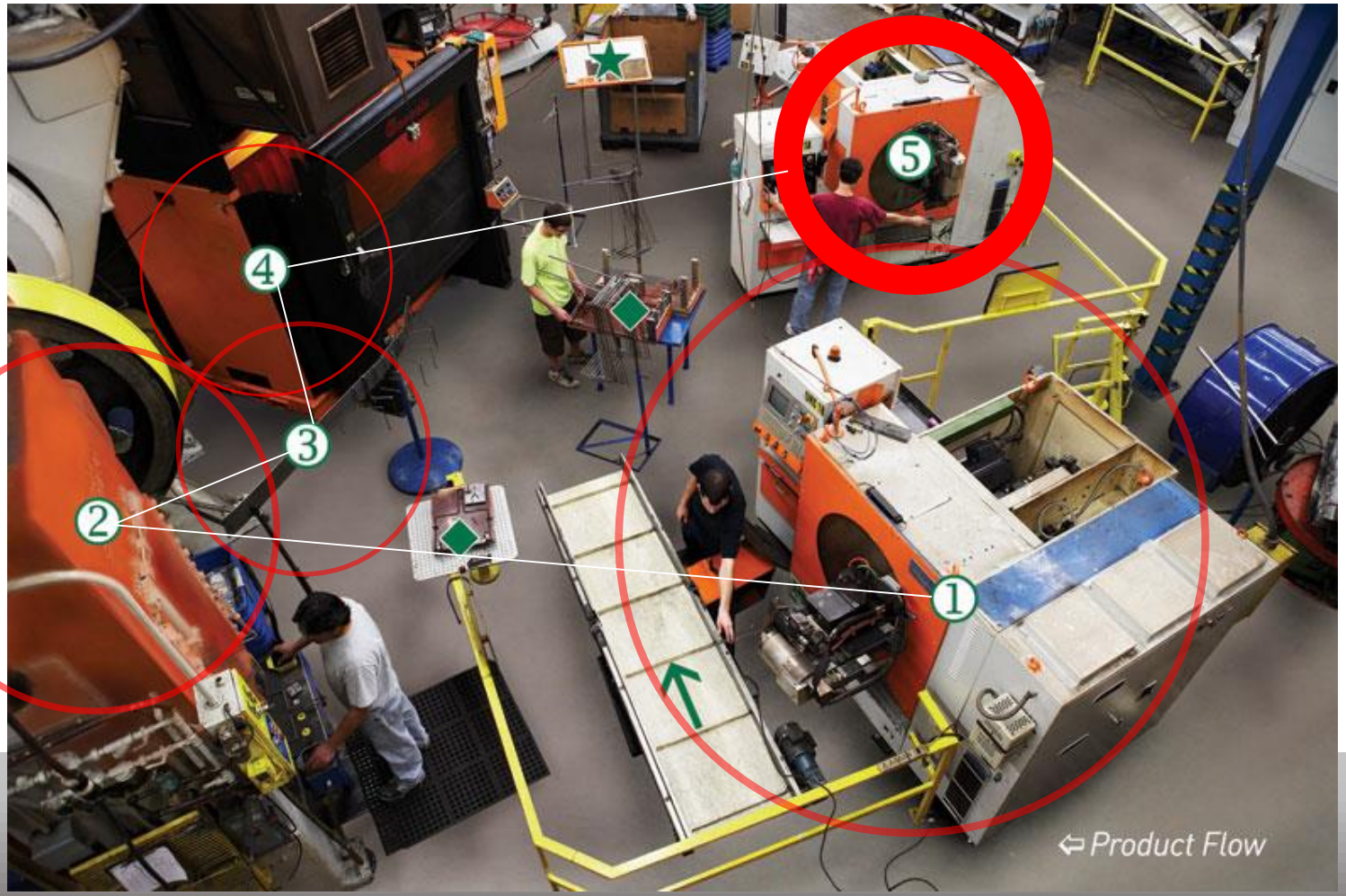
CELL DESIGN



CELL DESIGN



CELL DESIGN



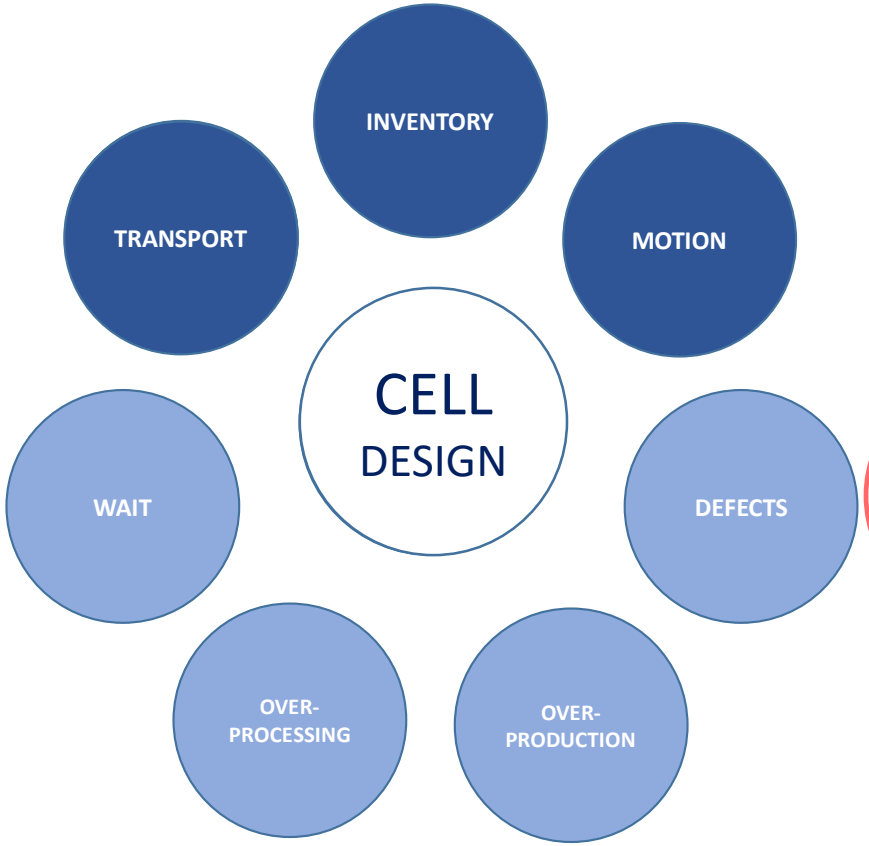
QUESTION 4

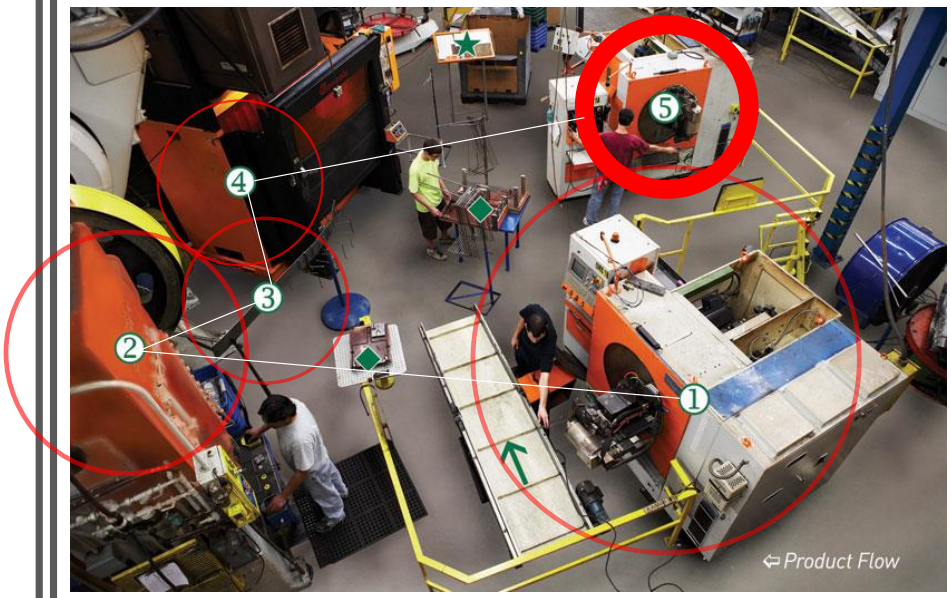
CELL DESIGN

Pass down your post-it notes if you raised your hand.

WASTE ADDRESSED

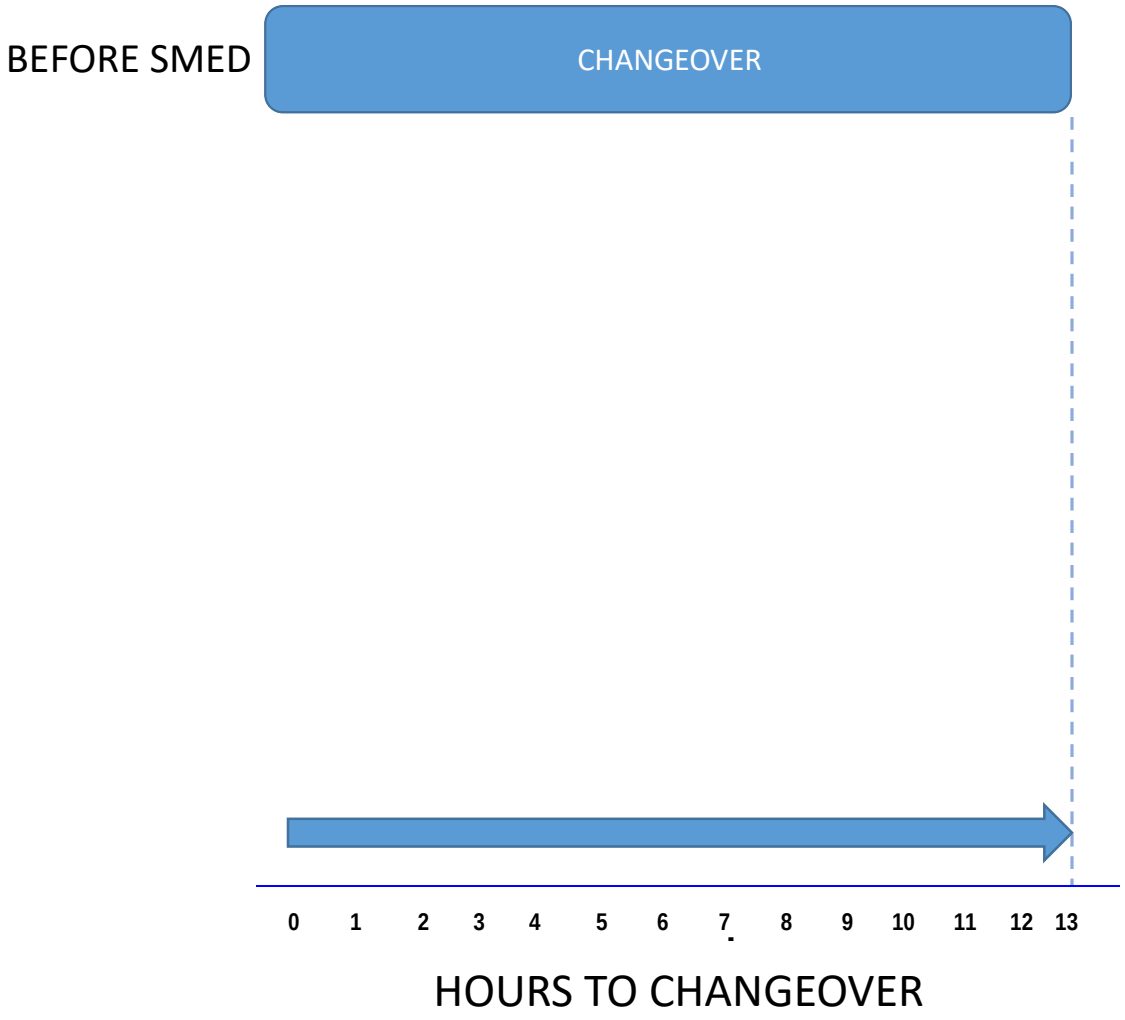
QUESTION 4 – CELL DESIGN





SMED

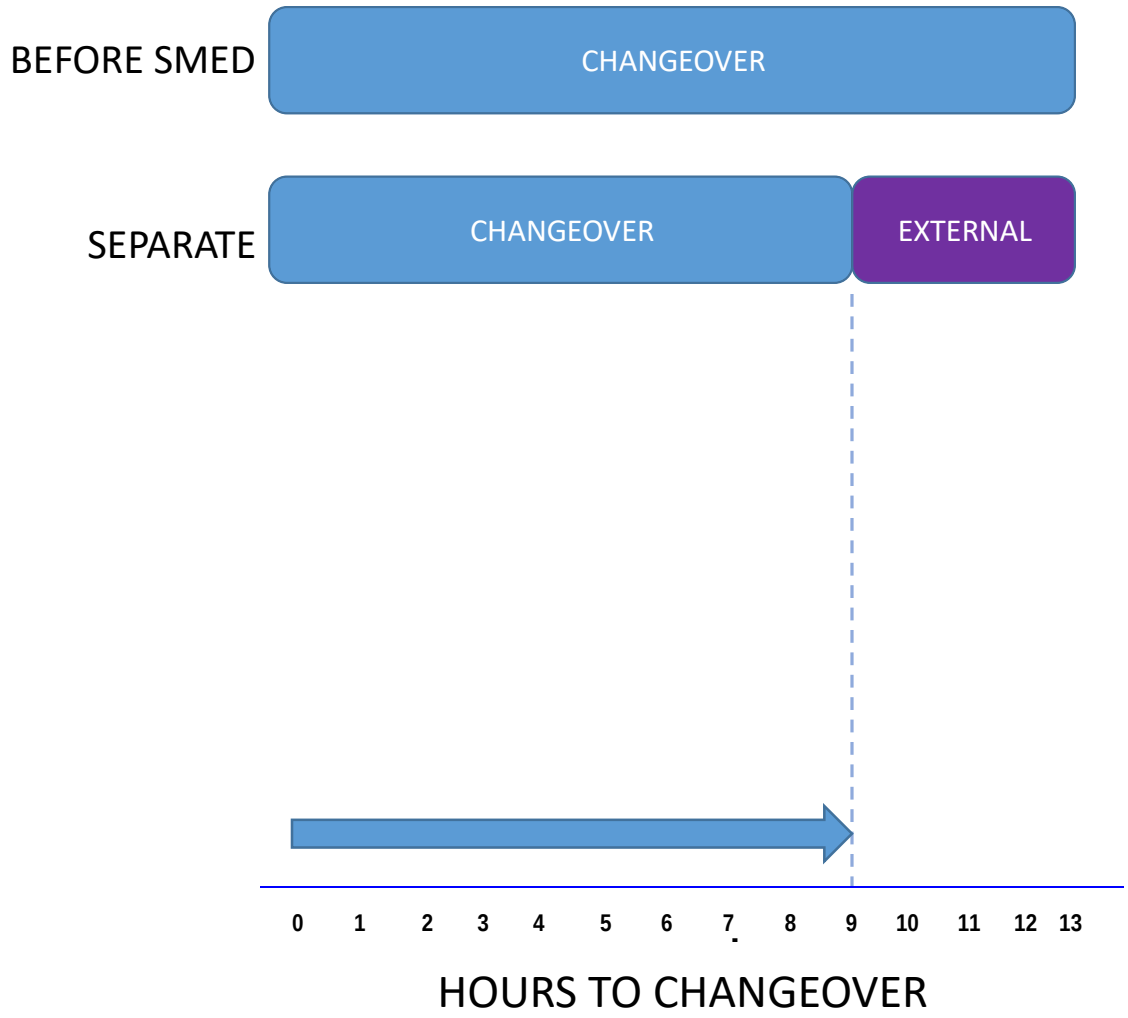
(QUICK CHANGE)



SEPARATE ----- EXTERNAL & INTERNAL

SMED

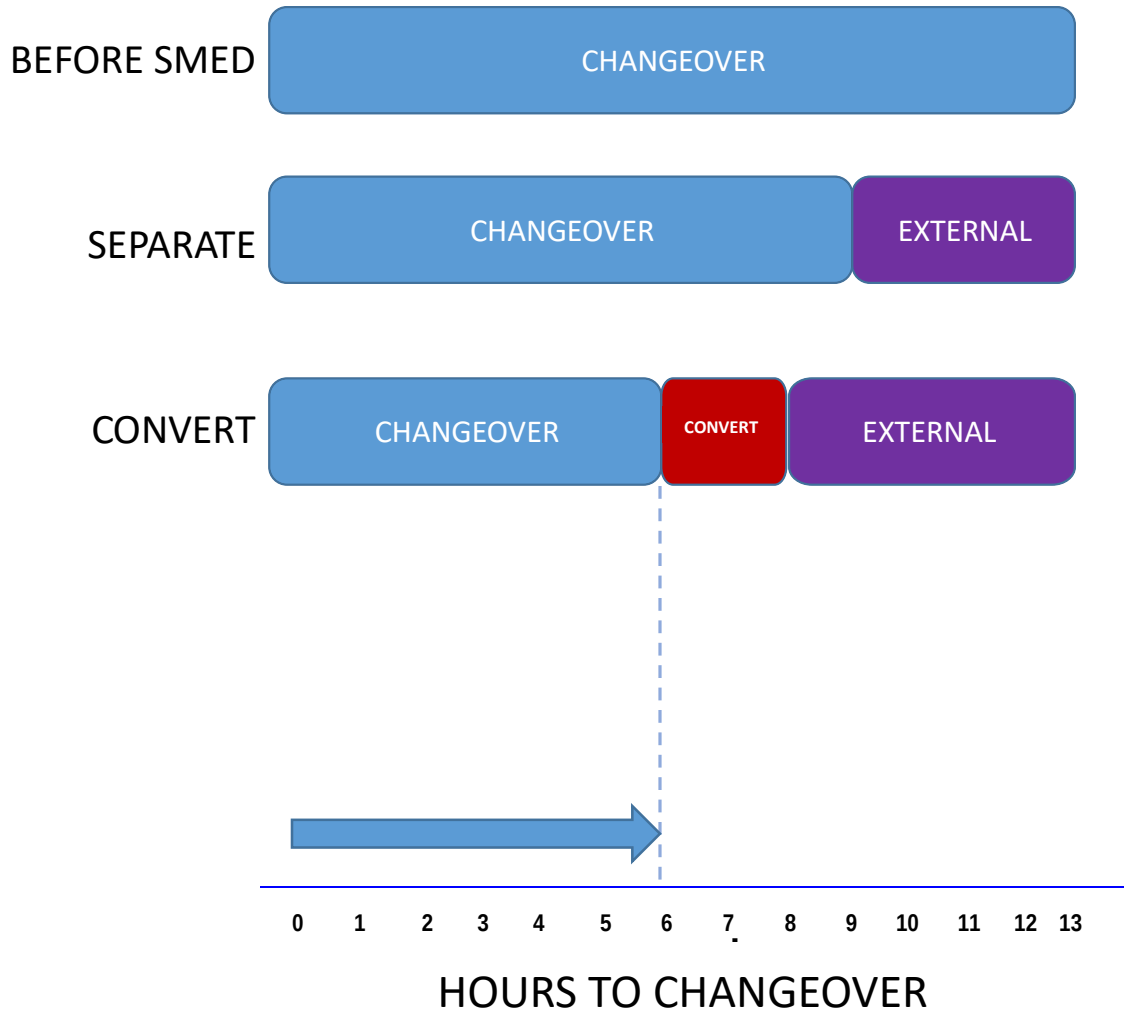
(QUICK CHANGE)



CONVERT ----- INTERNAL TO EXTERNAL

SMED

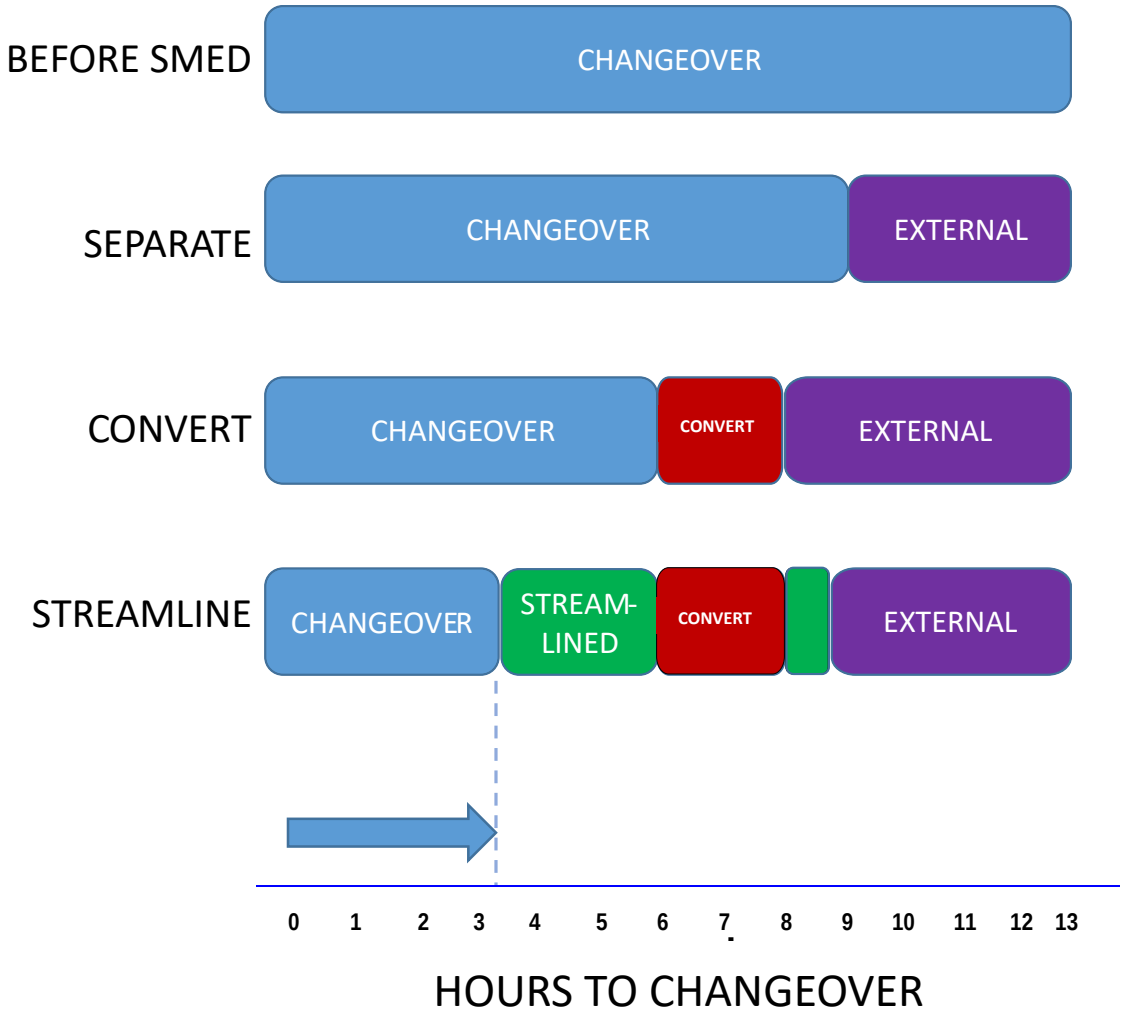
(QUICK CHANGE)



STREAMLINE -- INTERNAL & EXTERNAL

SMED

(QUICK CHANGE)



SMED

(QUICK CHANGE)

https://www.youtube.com/watch?v=UlIGI3laGAo

QUESTION 5

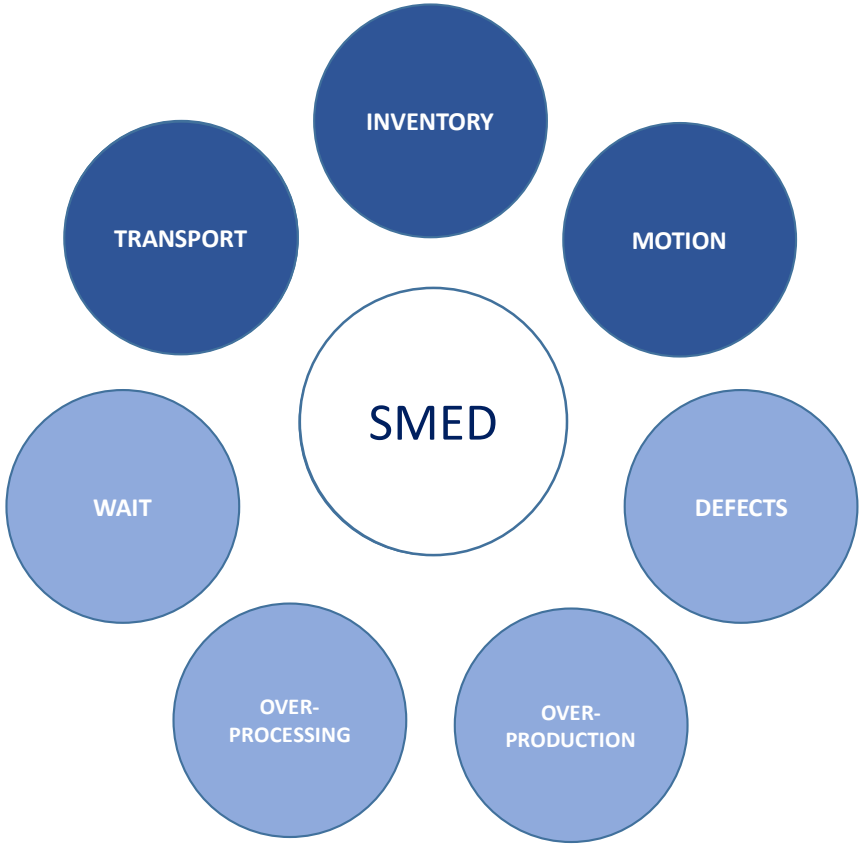
SMED

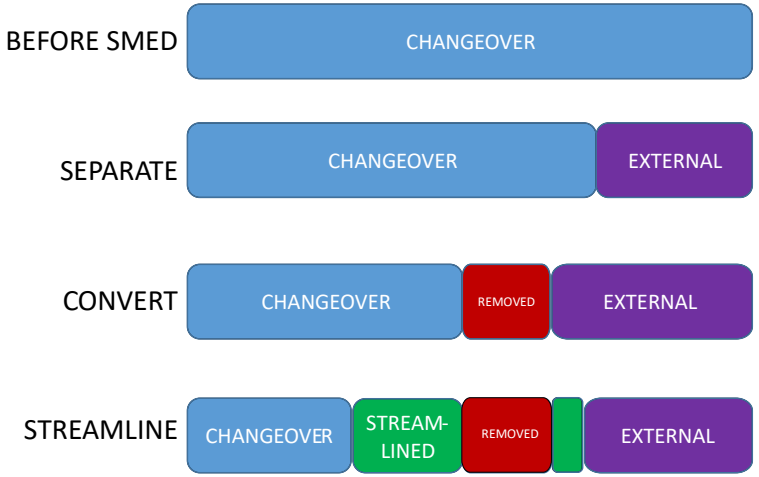
(QUICK CHANGE)

Pass down your post-it notes if you raised your hand.

WASTE ADDRESSED

QUESTION 5 – SMED





SIX SIGMA -- CENTRAL THEMES

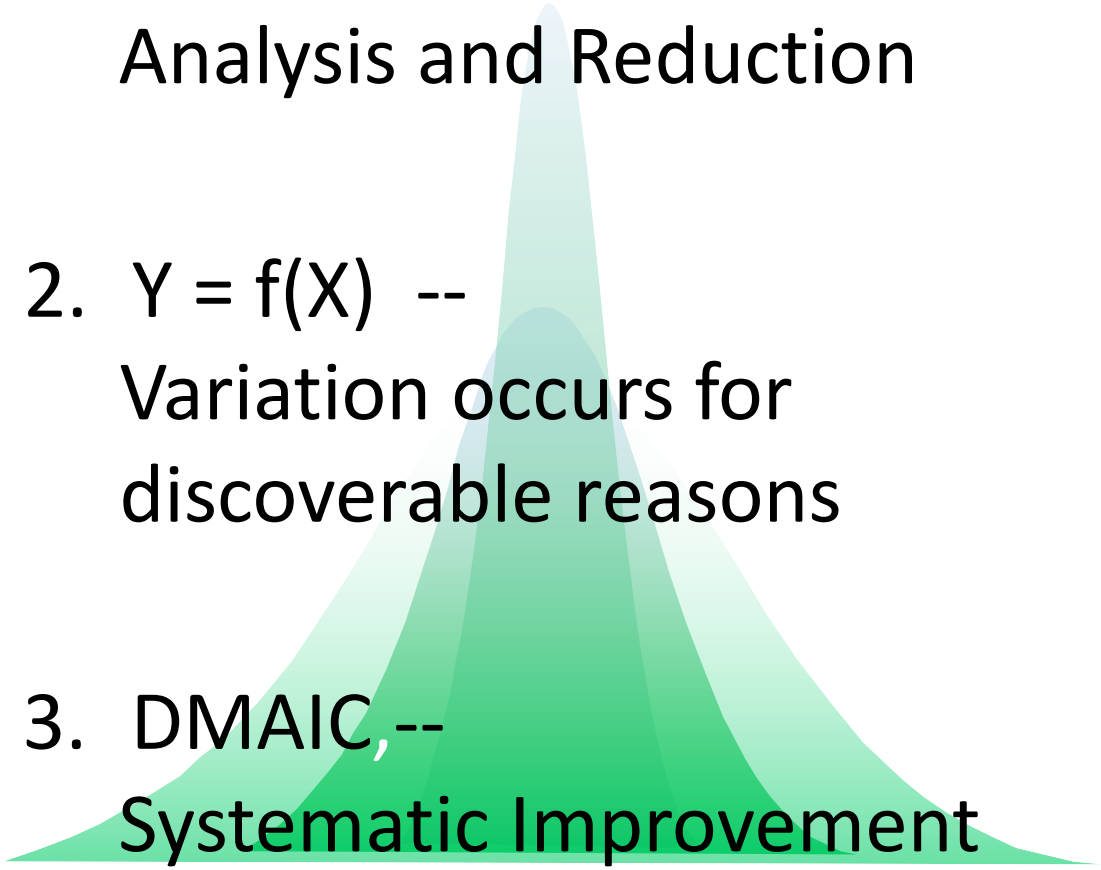
THREE THEMES

SIX SIGMA

1. VARIATION --
   Analysis and Reduction

2. Y = f(X) --
   Variation occurs for discoverable reasons

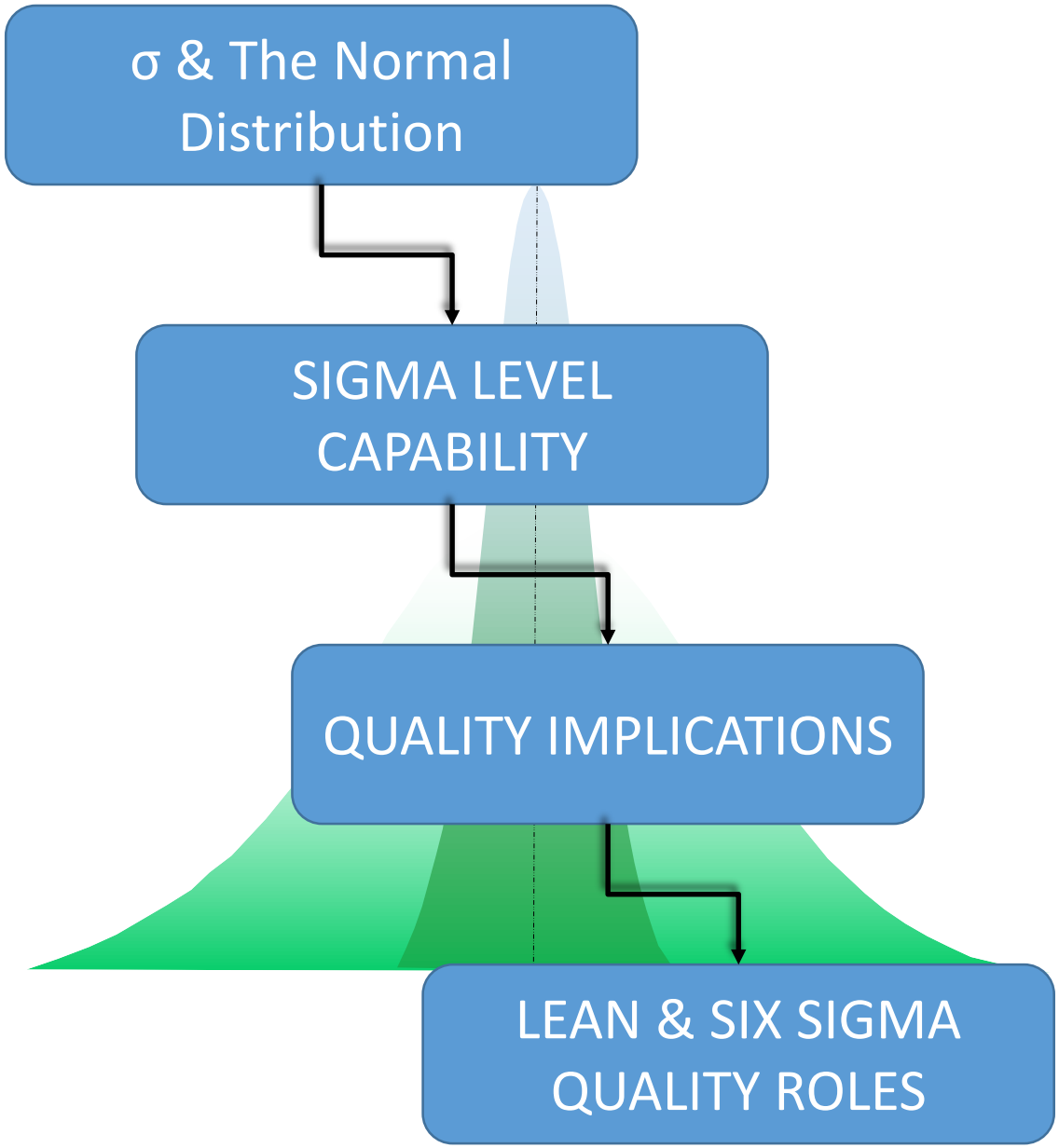
3. DMAIC,--
   Systematic Improvement



VARIATION –

Analysis/Reduction

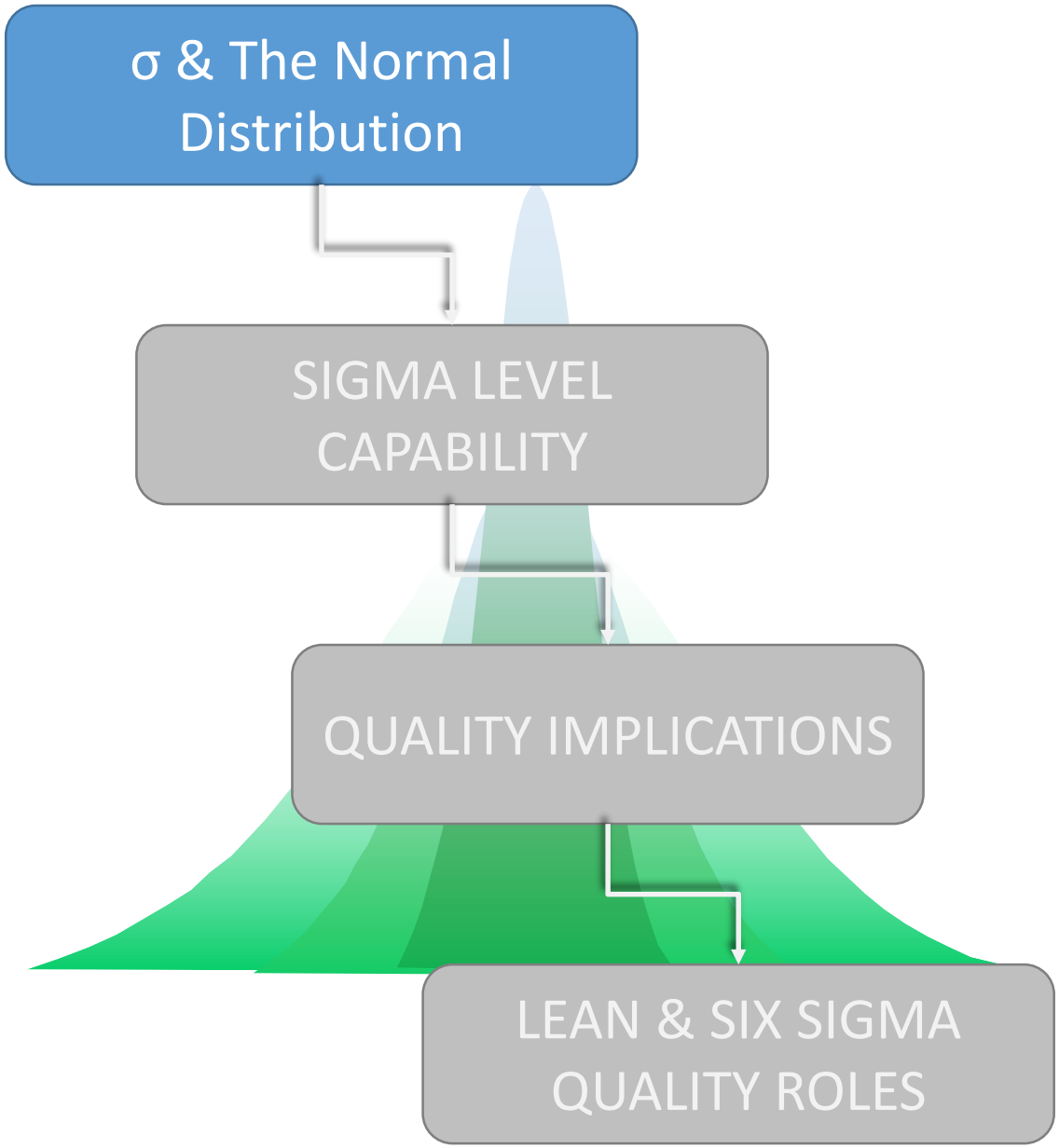
SIX SIGMA
THEME 1



VARIATION –

Analysis/Reduction

SIX SIGMA
THEME 1



VARIATION –

Analysis/Reduction

SIX SIGMA
THEME 1

Six Sigma ?

VARIATION –

Analysis/Reduction

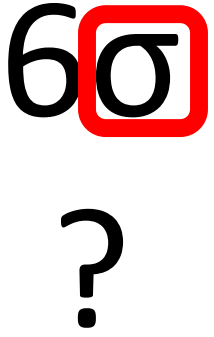
SIX SIGMA
THEME 1

6 sigma ?

VARIATION –

Analysis/Reduction

SIX SIGMA
THEME 1



VARIATION –

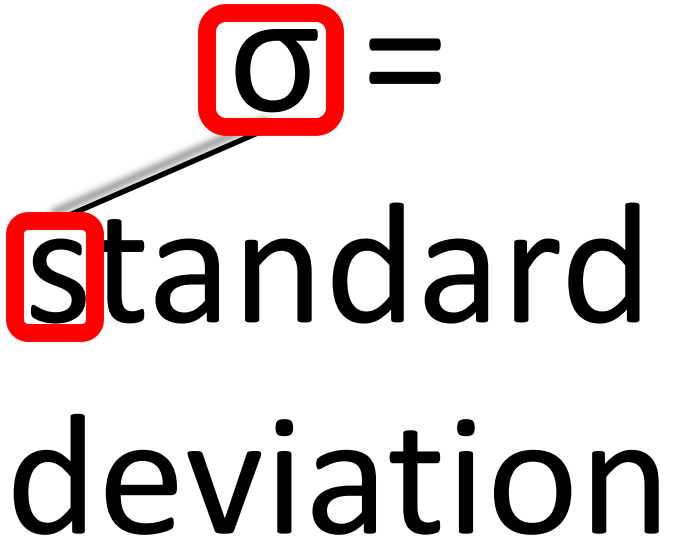
Analysis/Reduction

SIX SIGMA THEME 1

VARIATION –

Analysis/Reduction

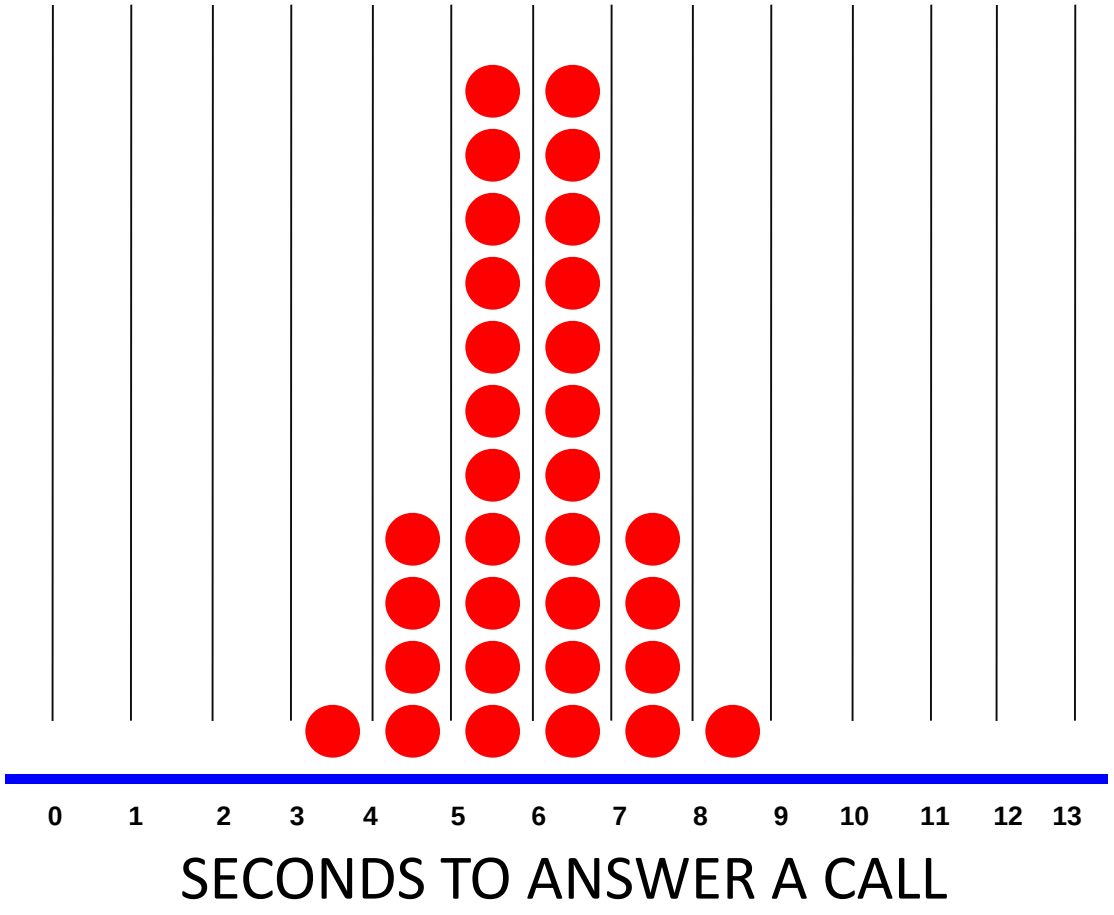
SIX SIGMA
THEME 1



VARIATION –

Analysis/Reduction

SIX SIGMA THEME 1

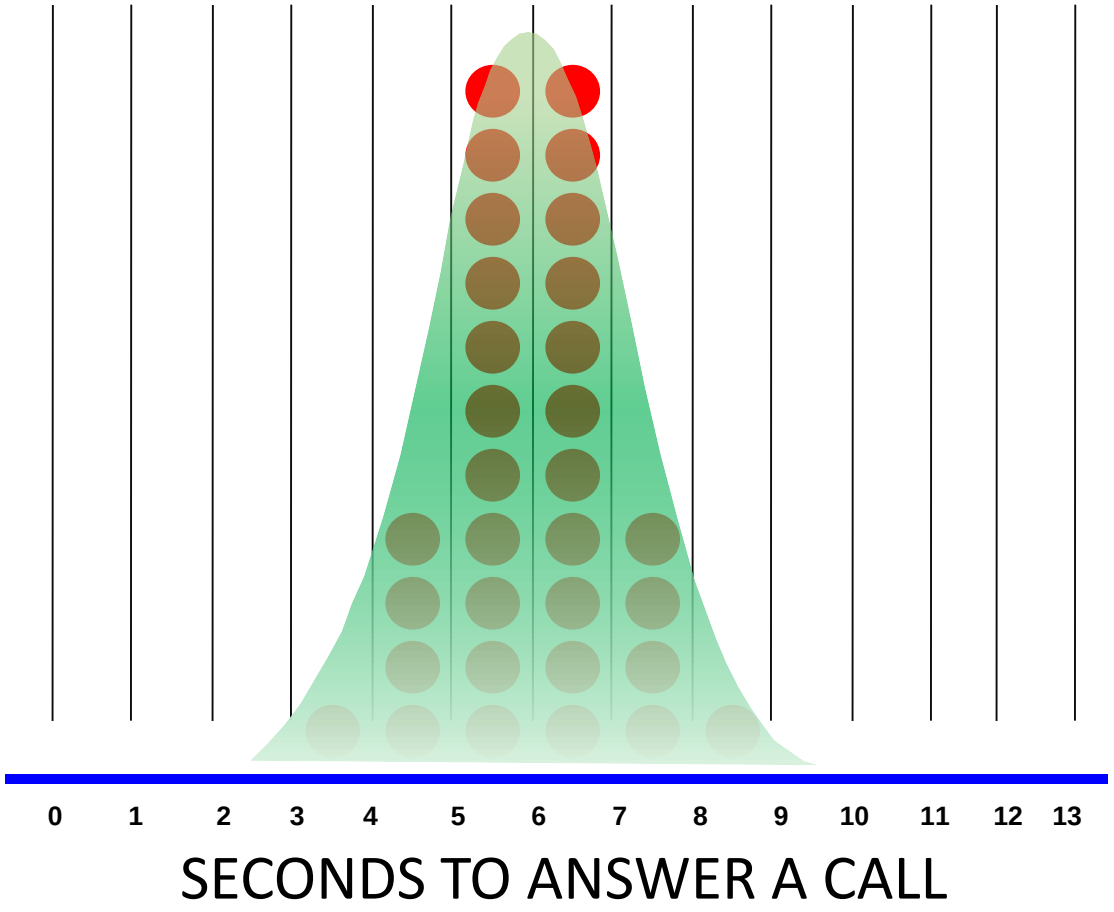


VARIATION –

Analysis/Reduction

SIX SIGMA
THEME 1

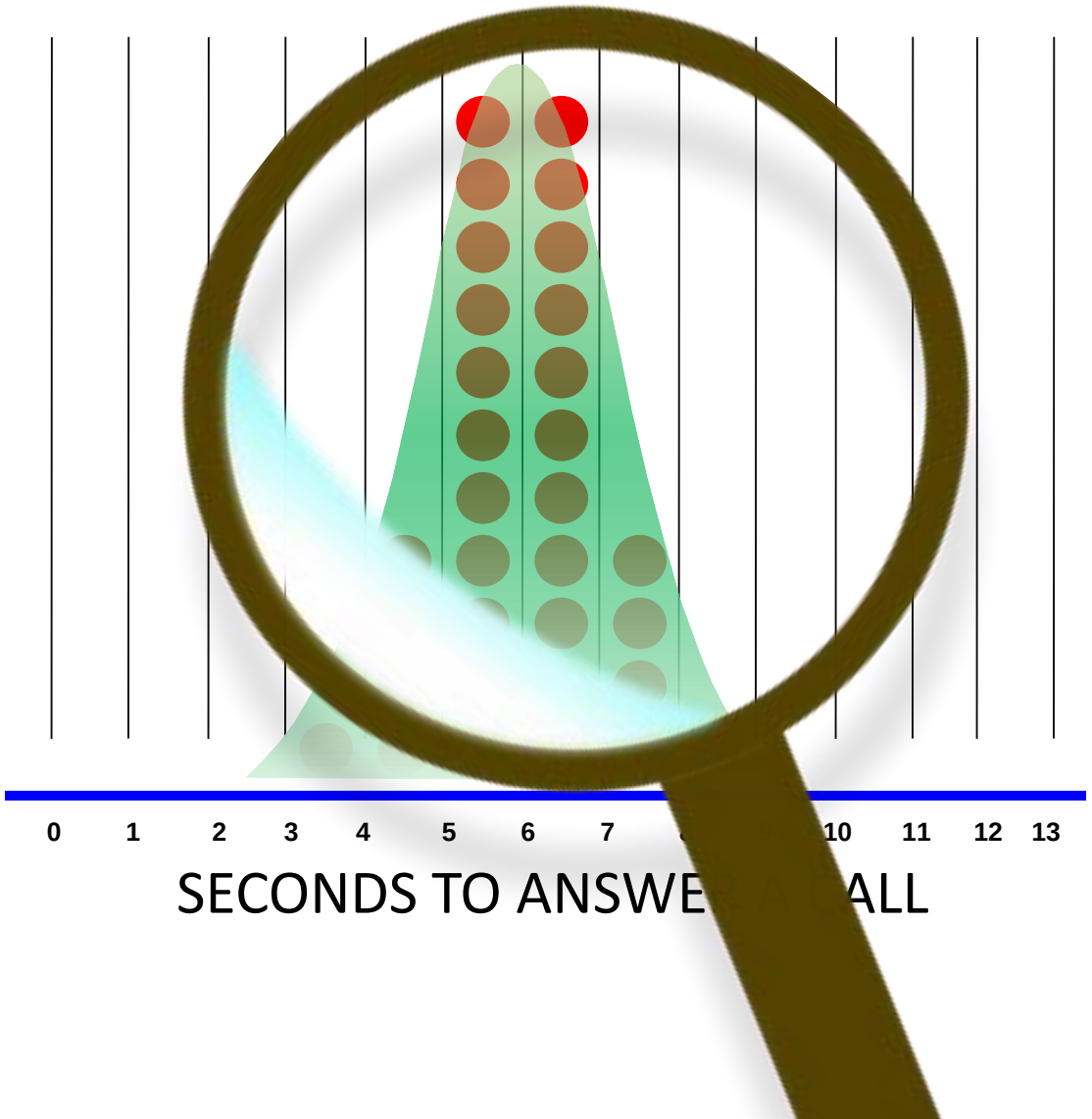
IS THIS NORMAL?

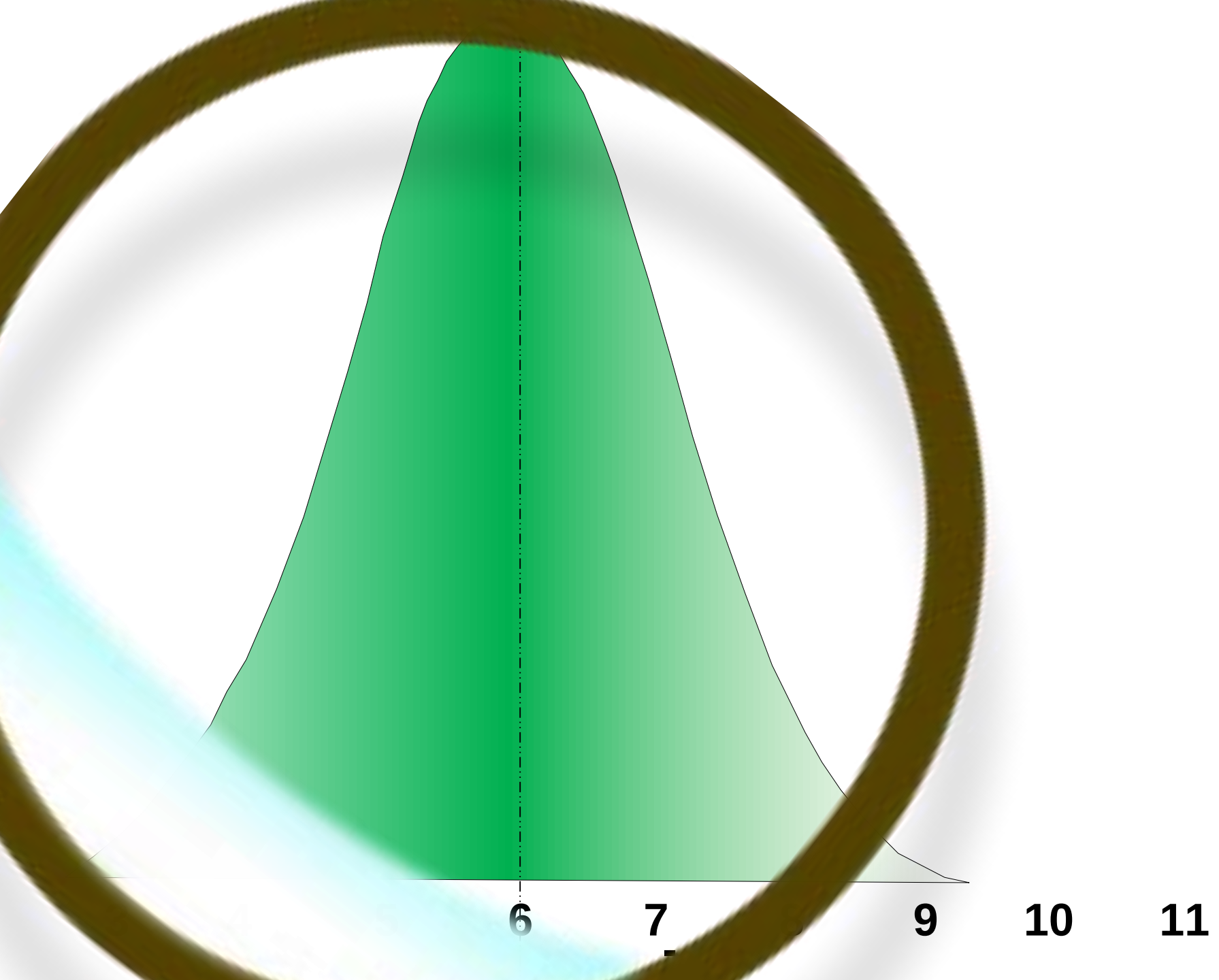


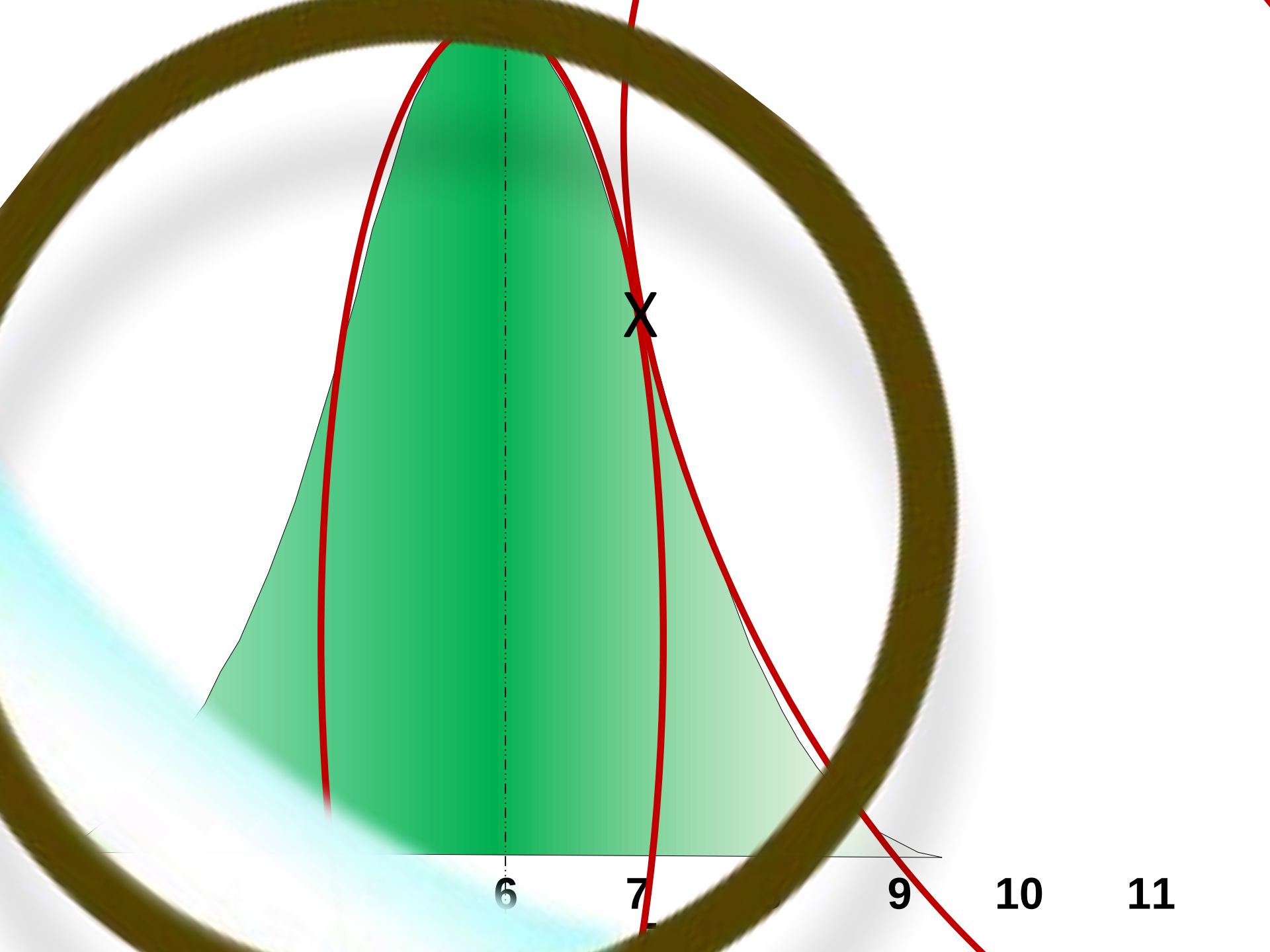
VARIATION –

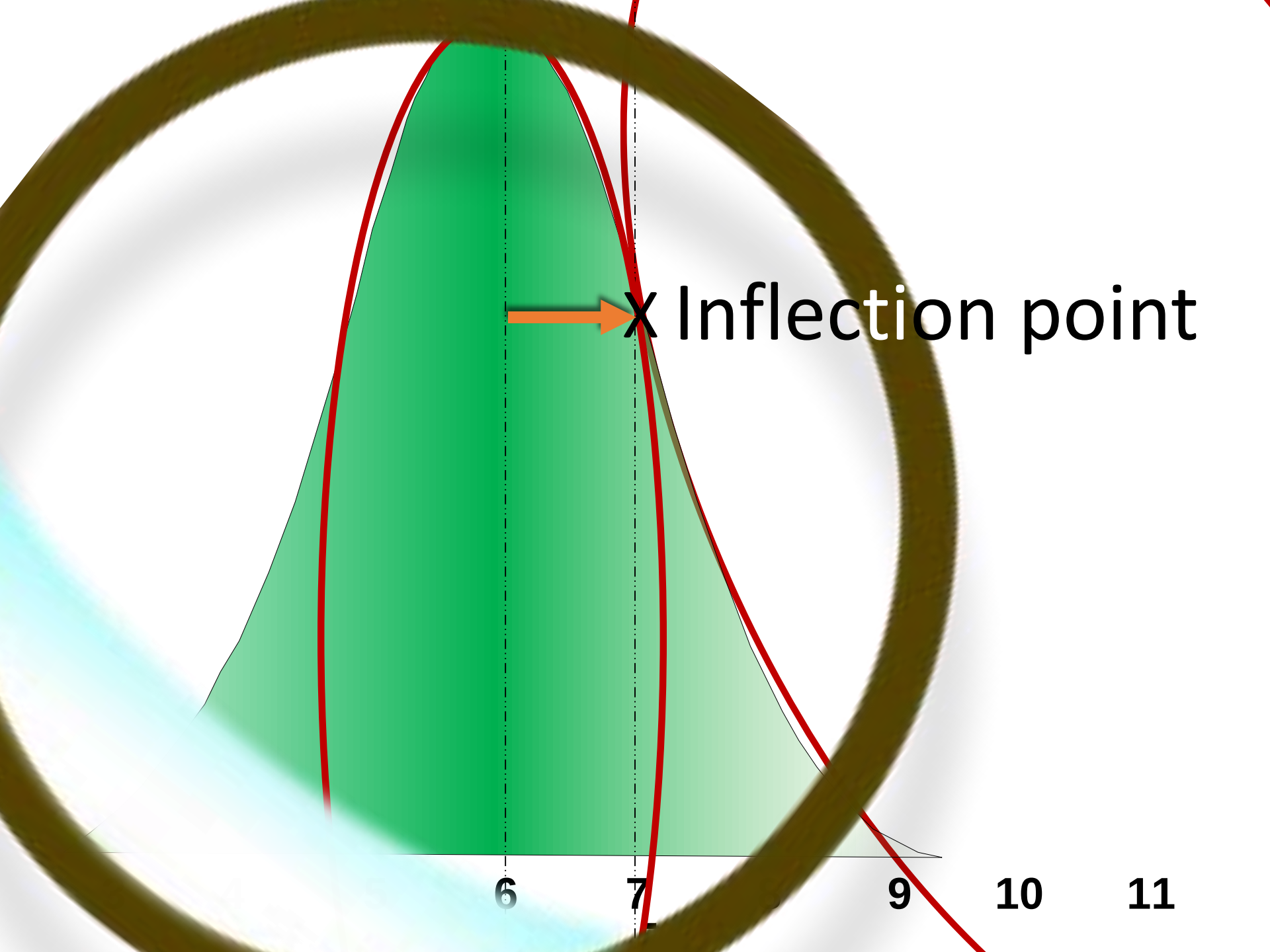
Analysis/Reduction

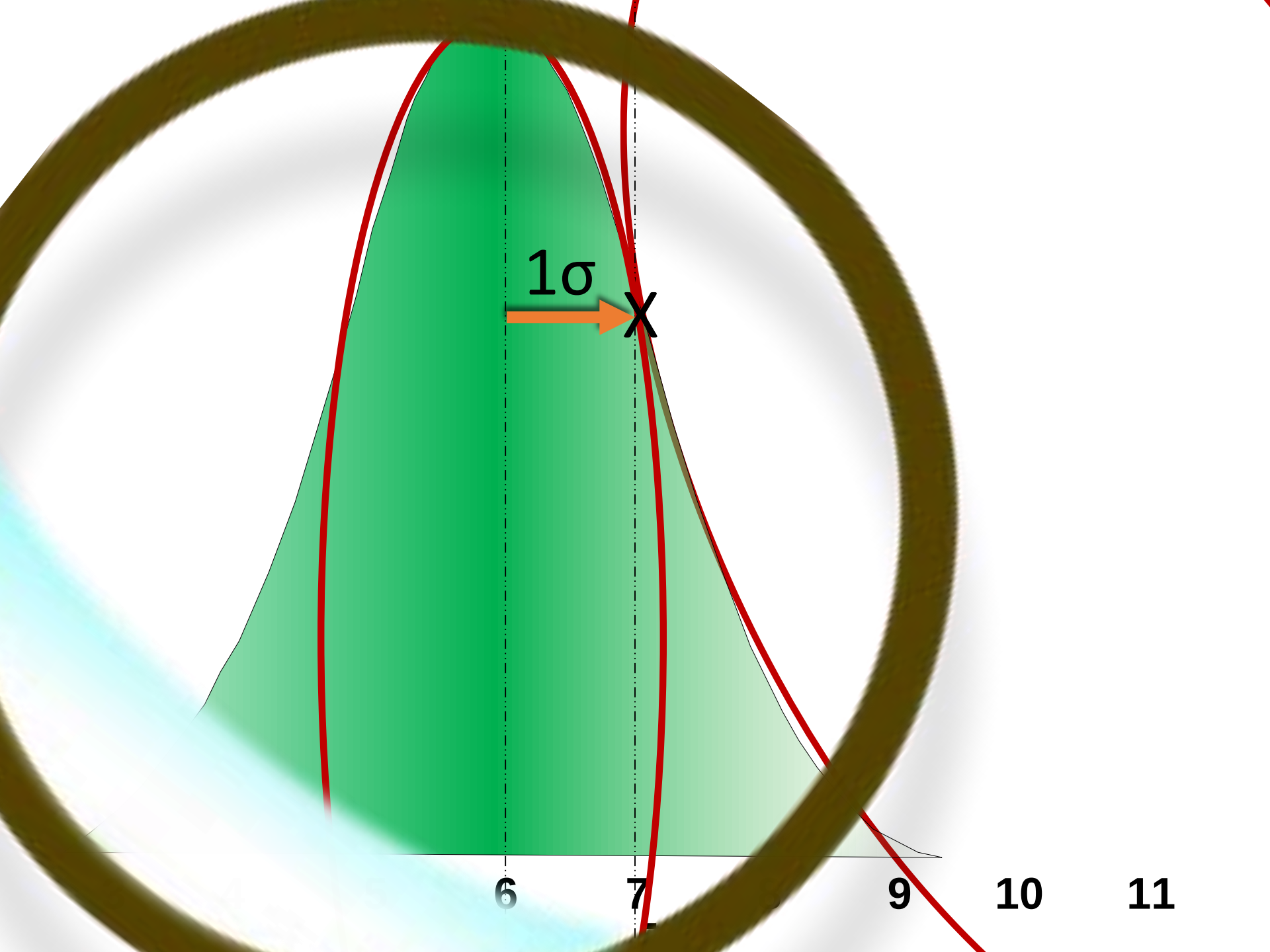
SIX SIGMA THEME 1

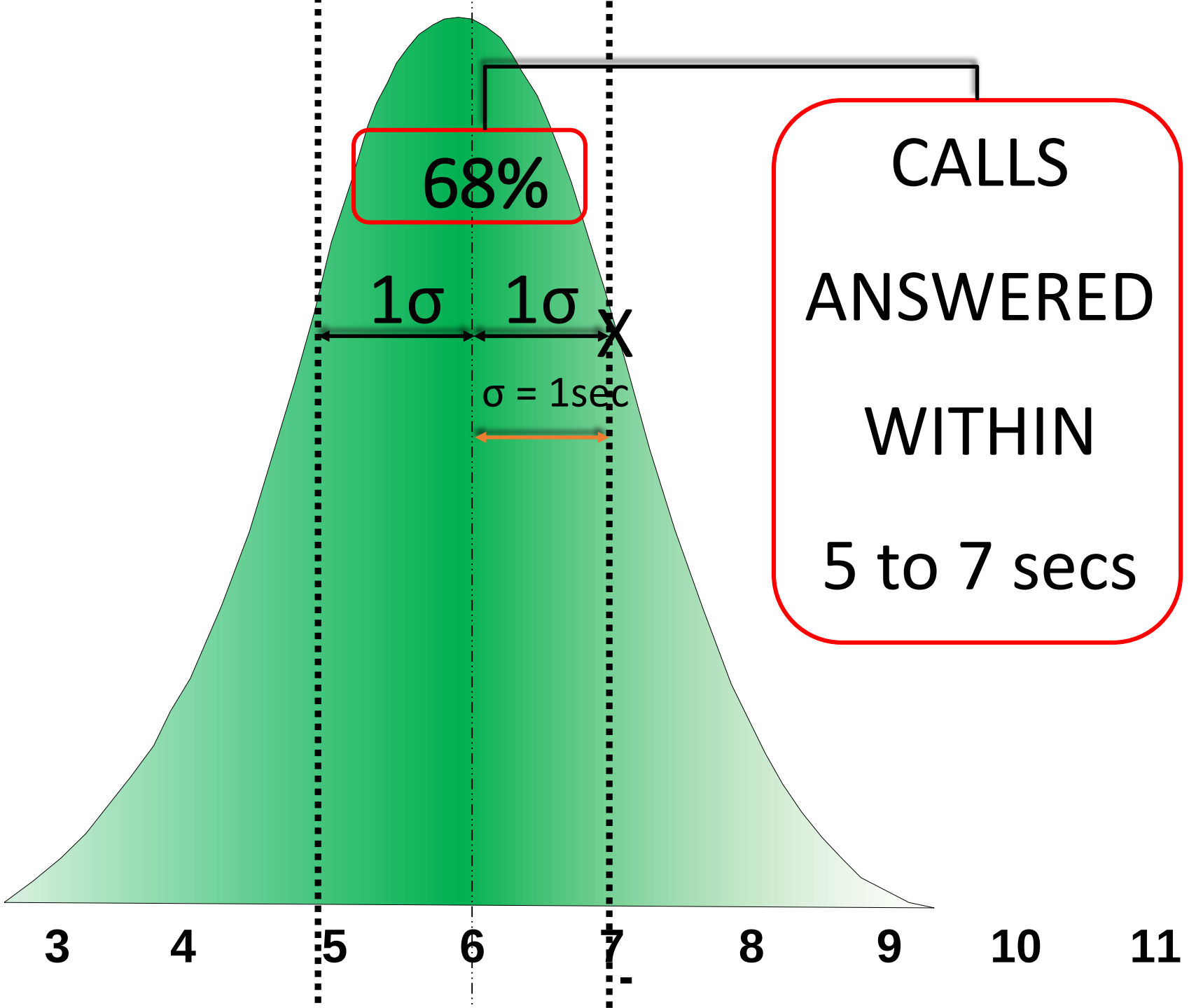


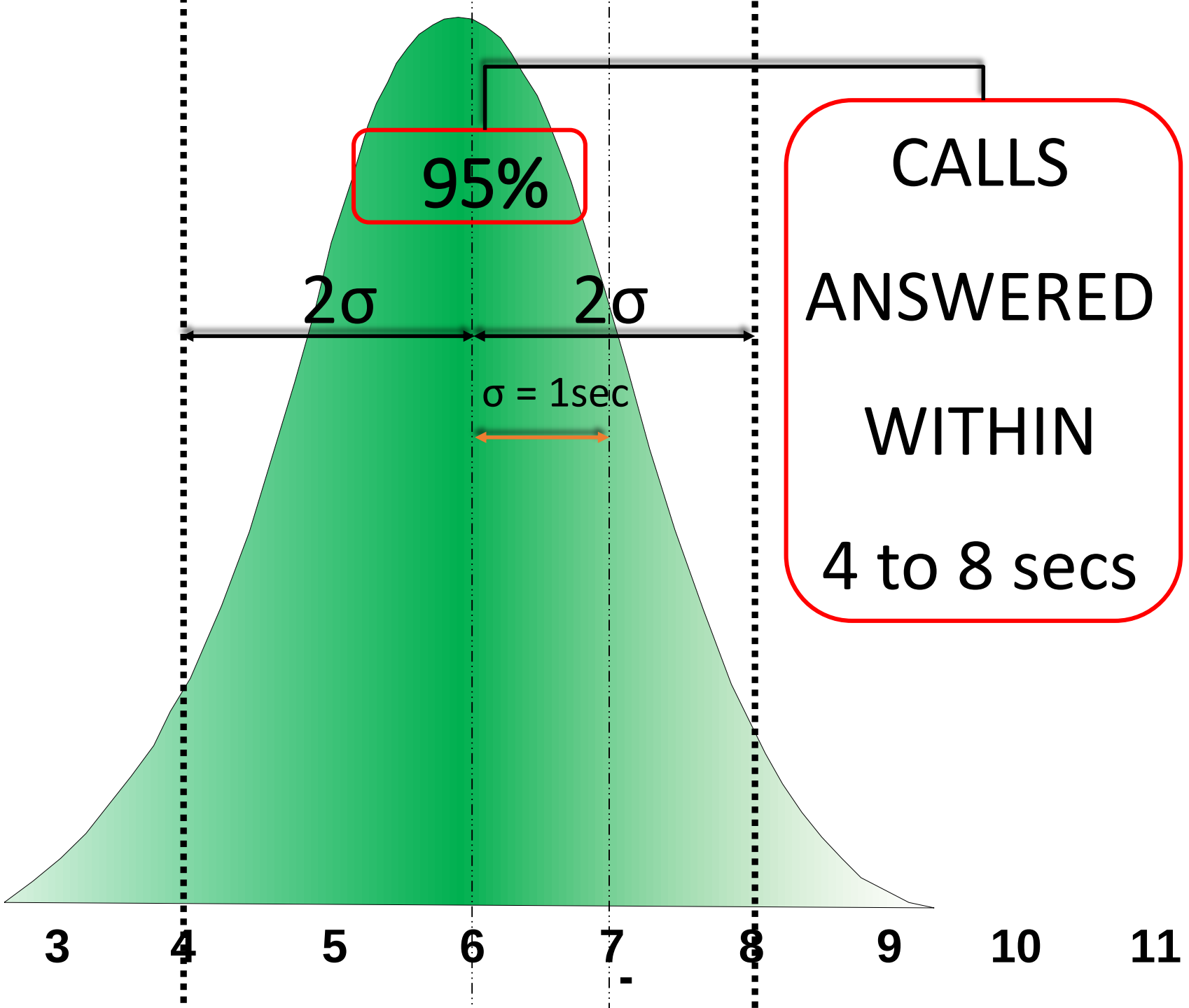

6
7
9
10
11

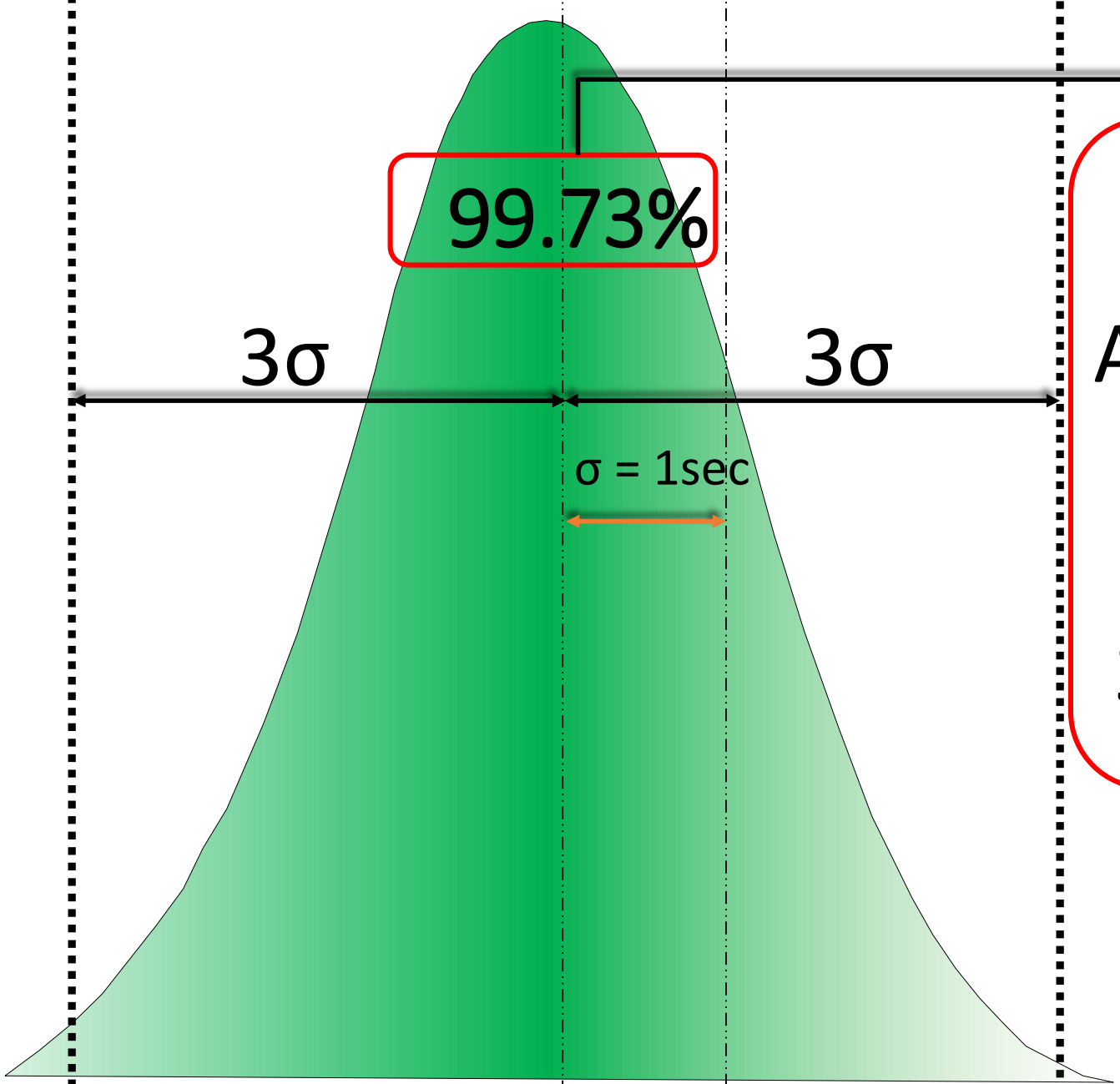

X
6
7
9
10
11


X Inflection point
6
7
9
10
11


1σ
X
6
7
9
10
11

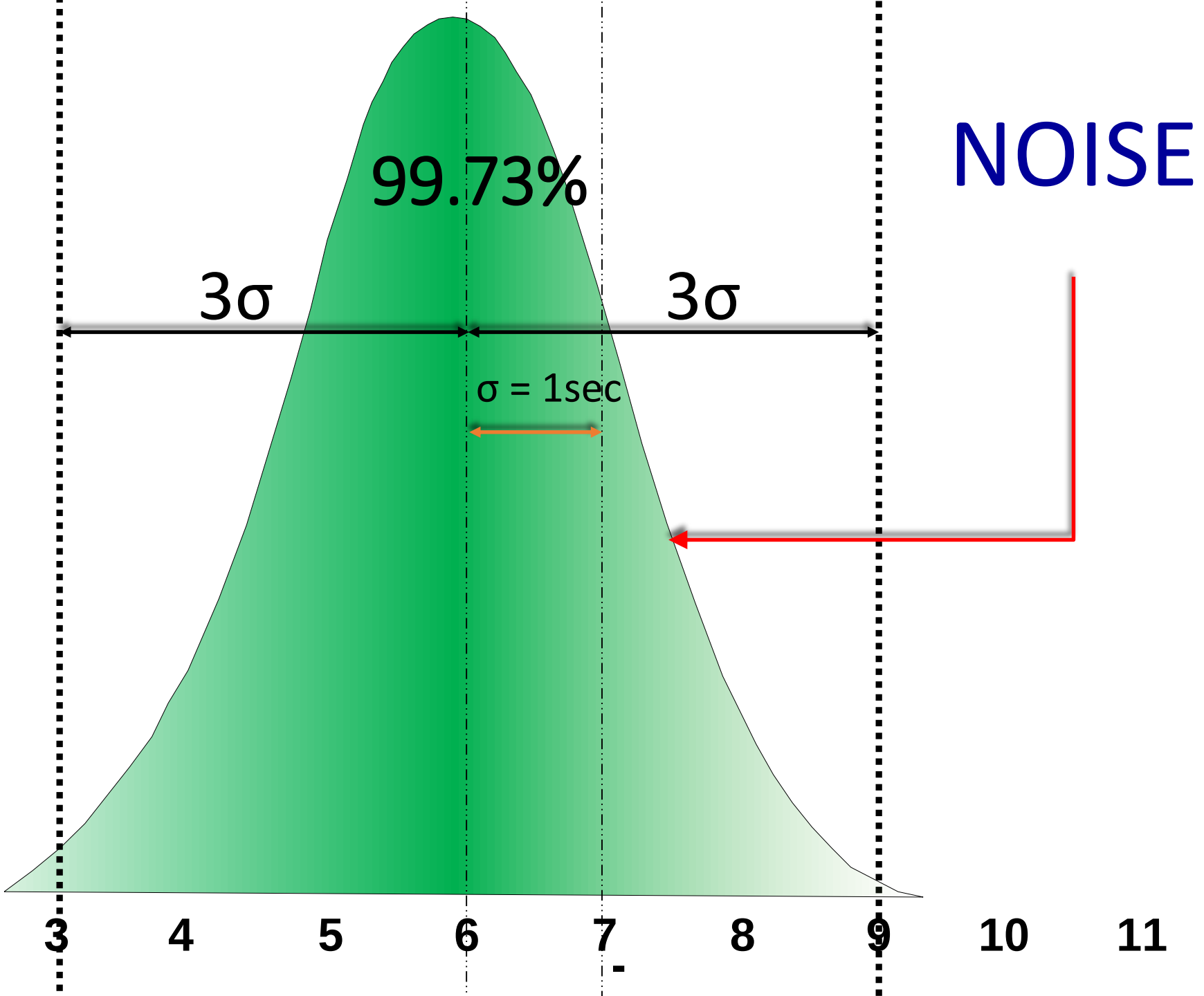

68%
1σ
1σ
X
σ = 1sec
CALLS
ANSWERED
WITHIN
5 to 7 secs
3
4
5
6
7
8
9
10
11

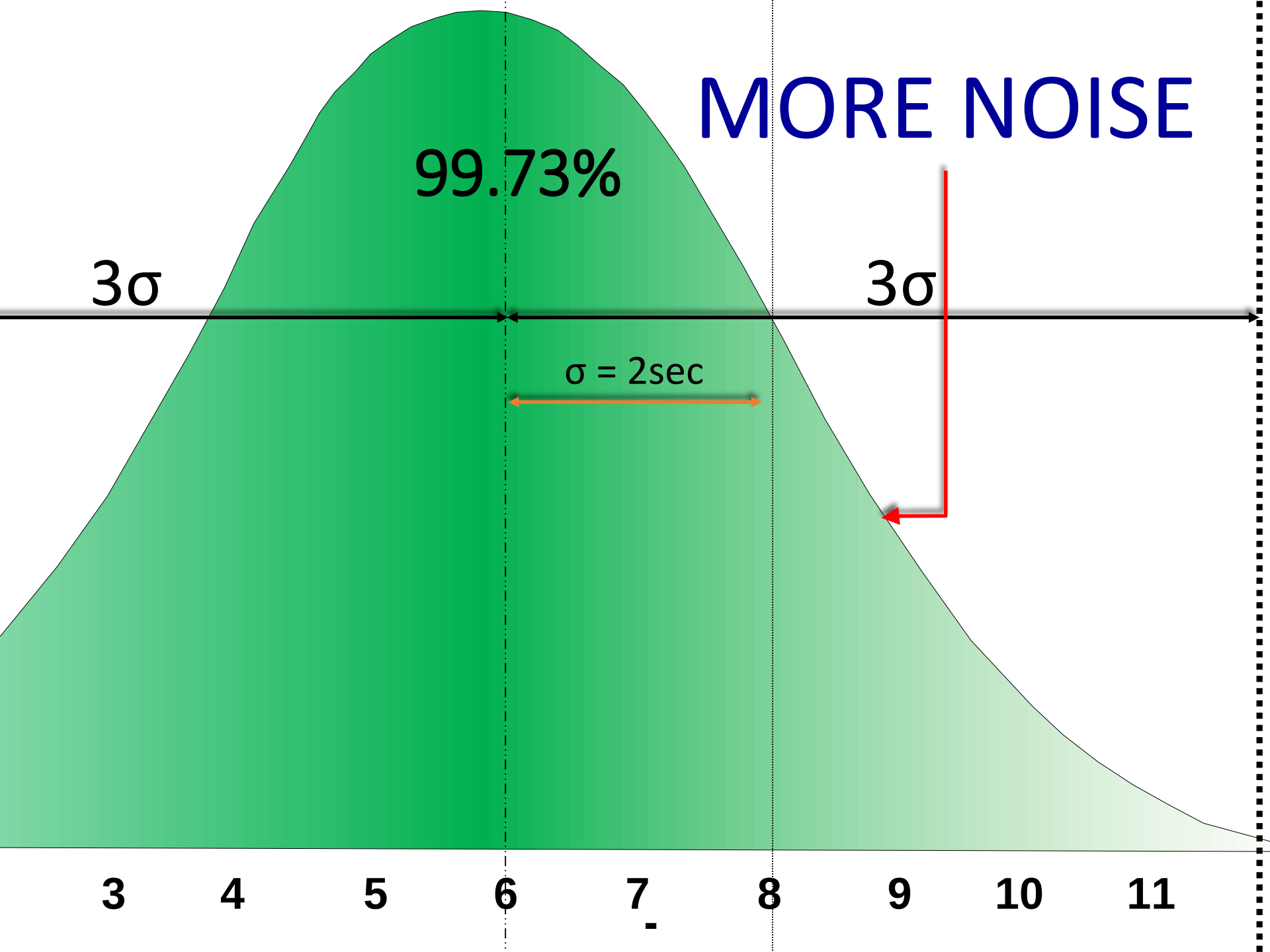

95%
2σ
2σ
σ = 1sec
CALLS
ANSWERED
WITHIN
4 to 8 secs
3
4
5
6
7
8
9
10
11

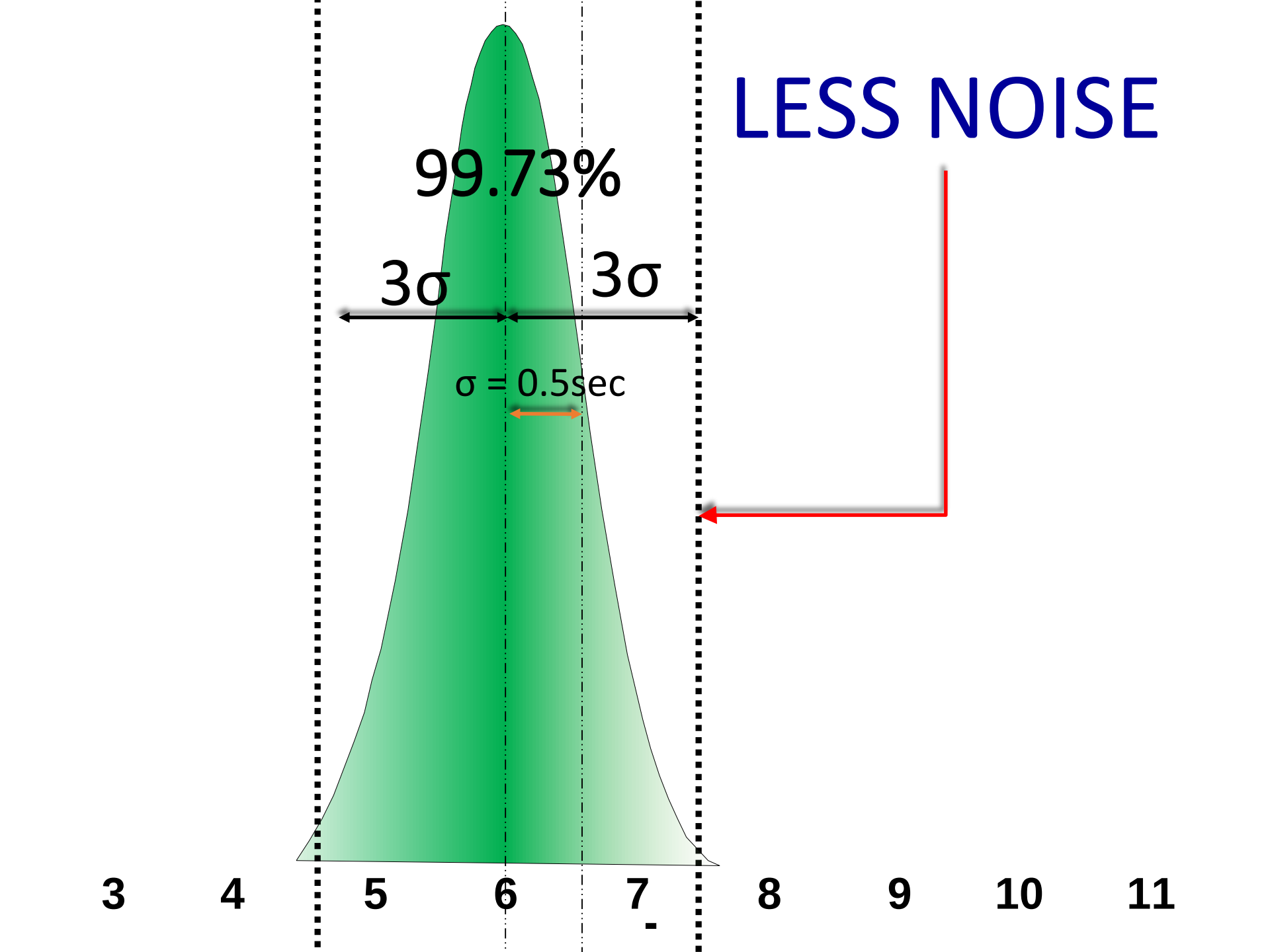


CALLS ANSWERED WITHIN 3 to 9 secs

3 4 5 6 7 8 9 10 11


NOISE
99.73%
3σ
3σ
σ = 1sec
3
4
5
6
7
8
9
10
11

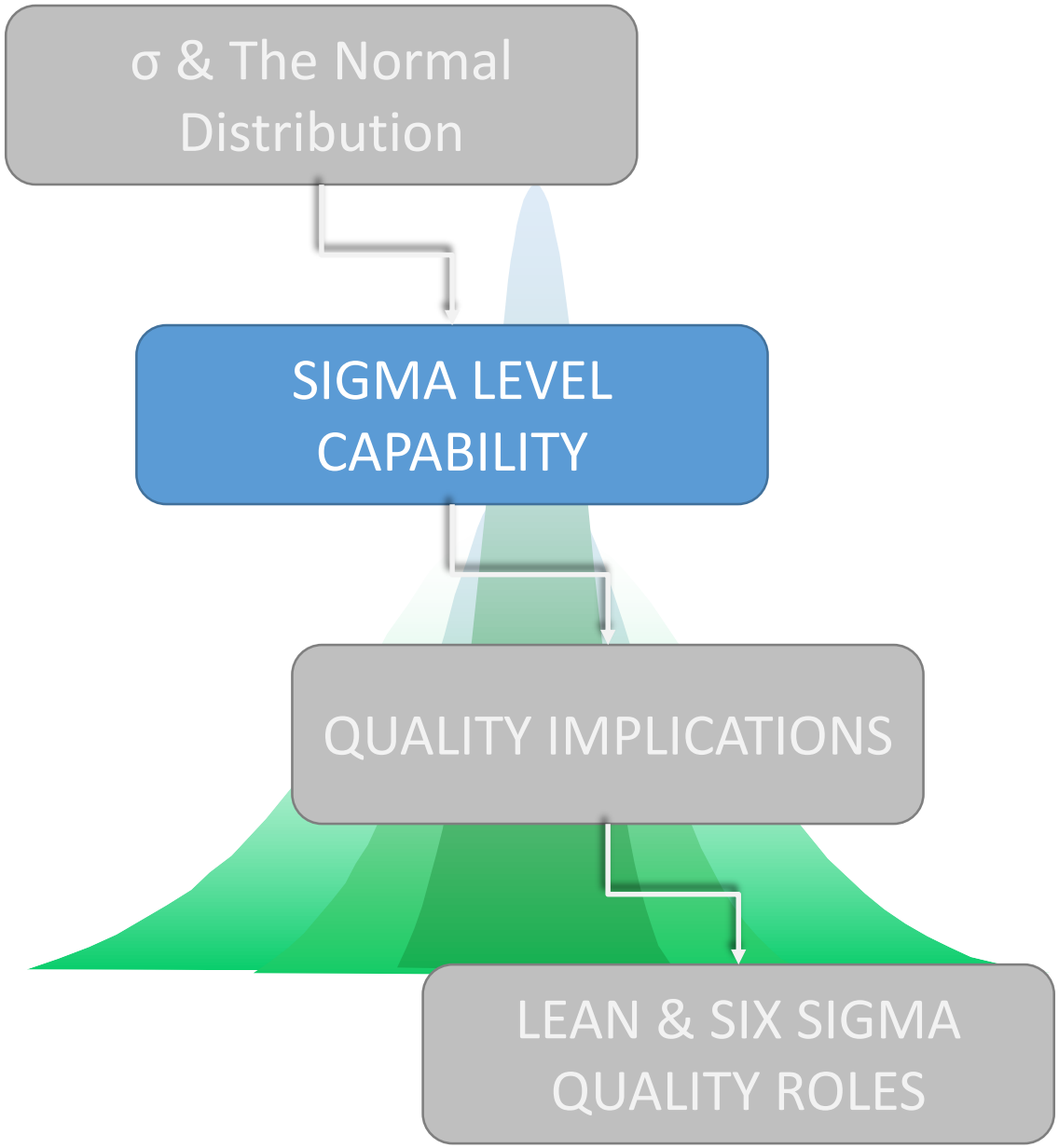

MORE NOISE
99.73%
3σ
3σ
σ = 2sec
3
4
5
6
7
8
9
10
11

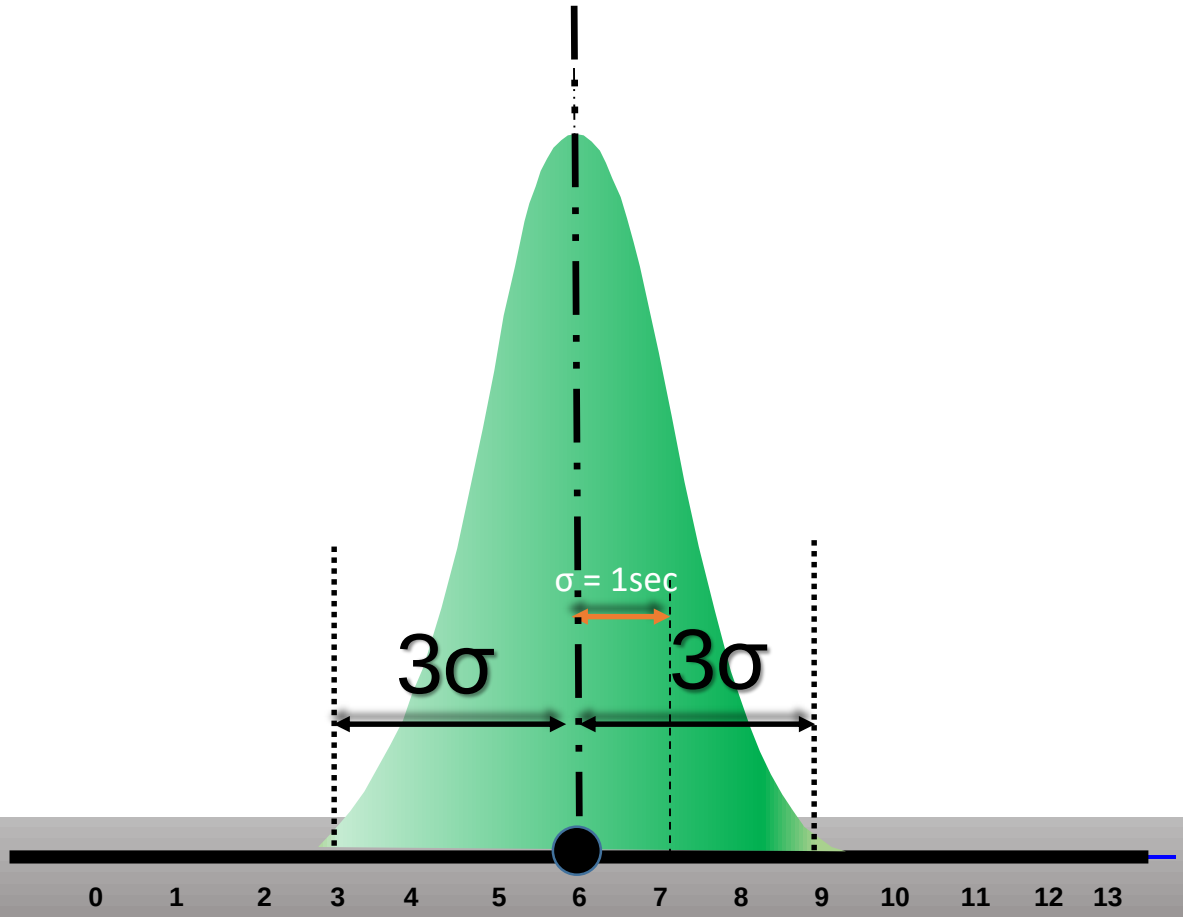

LESS NOISE
99.73%
3σ
3σ
σ = 0.5sec
3
4
5
6
7
8
9
10
11

VARIATION –

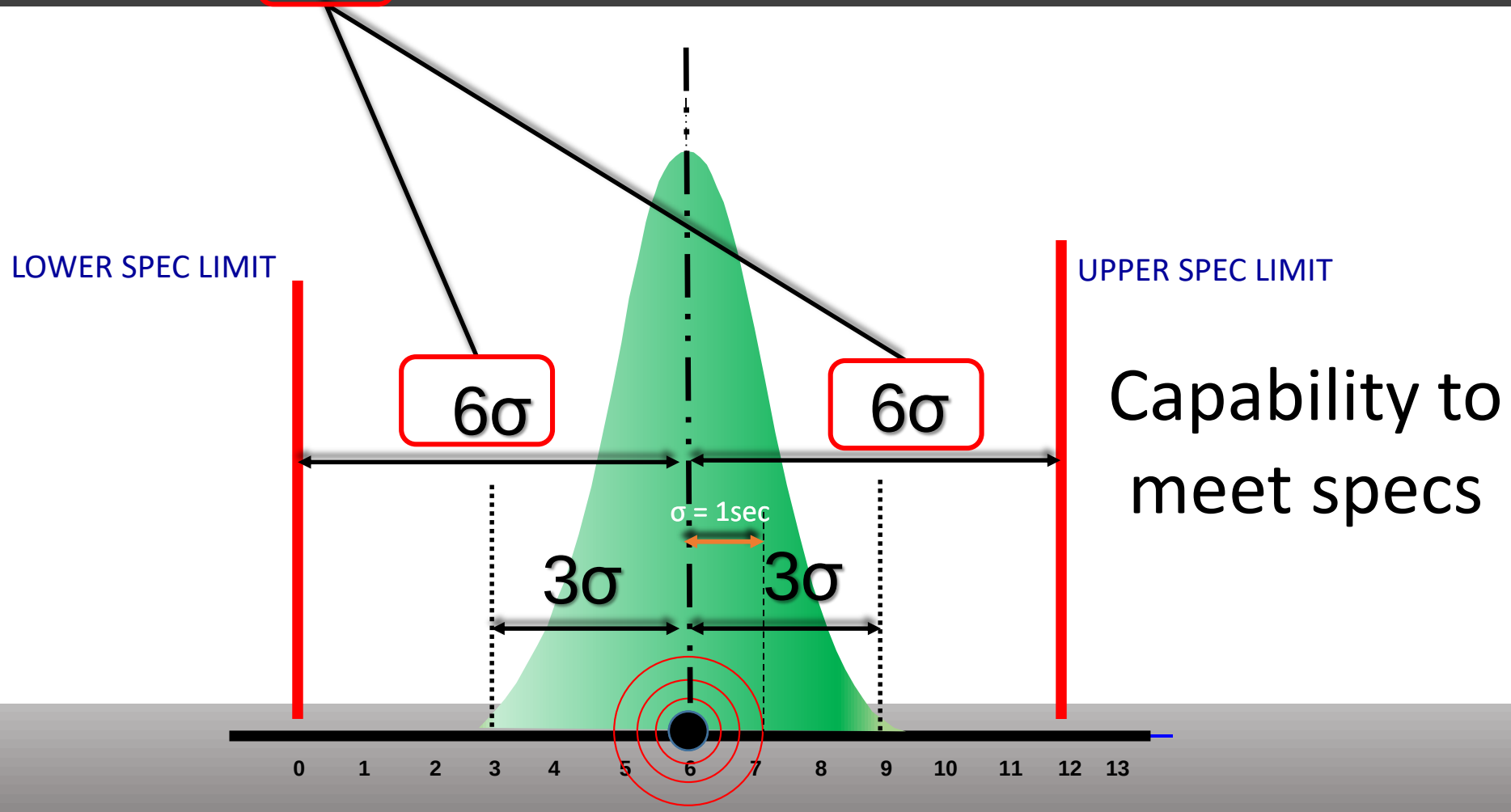
Analysis/Reduction

SIX SIGMA
THEME 1



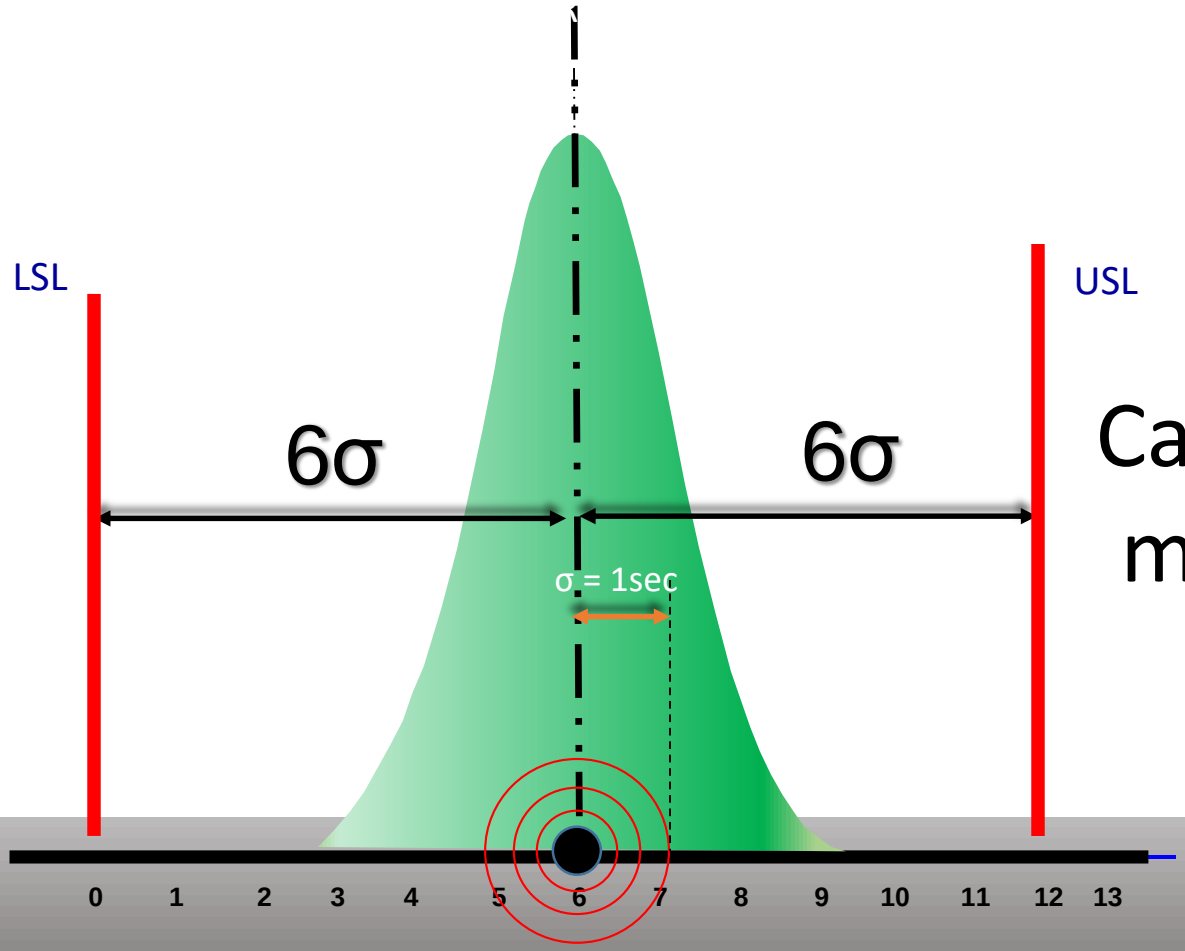

σ = 1sec
3σ
3σ
0
1
2
3
4
5
6
7
8
9
10
11
12
13

6σ PROCESS CAPABILITY



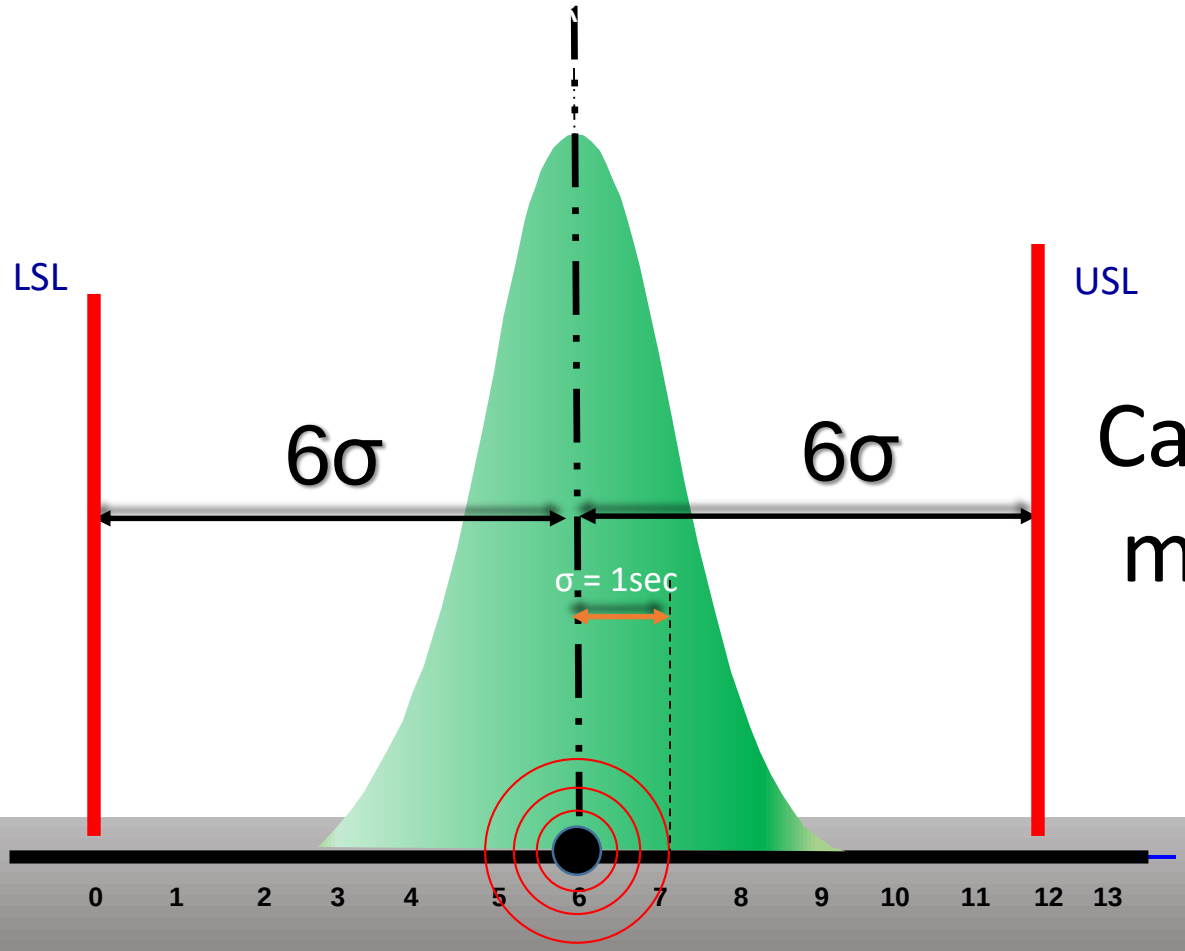
Capability to meet specs

0.002 Defects Per Million Opportunities



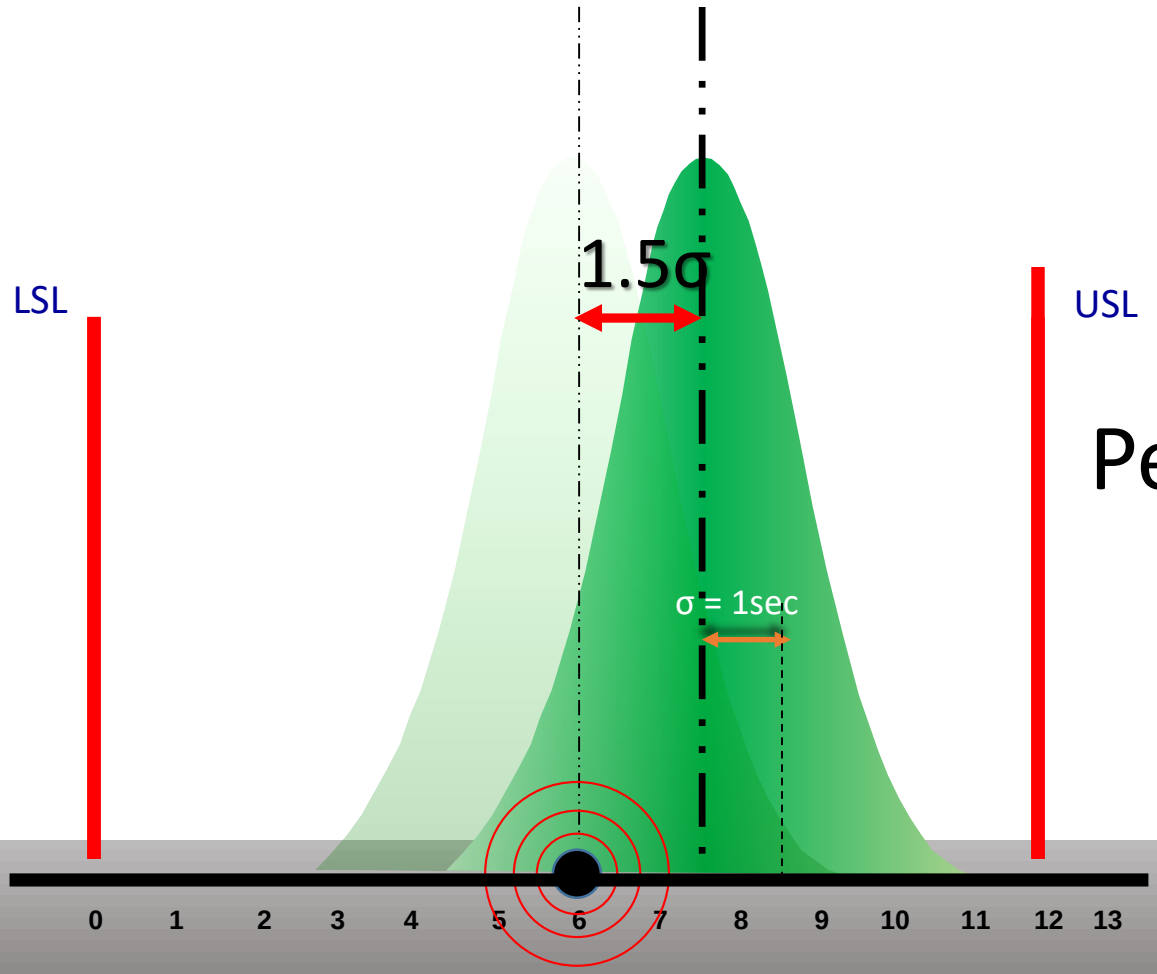
Capability to meet specs

0.002 DPMO



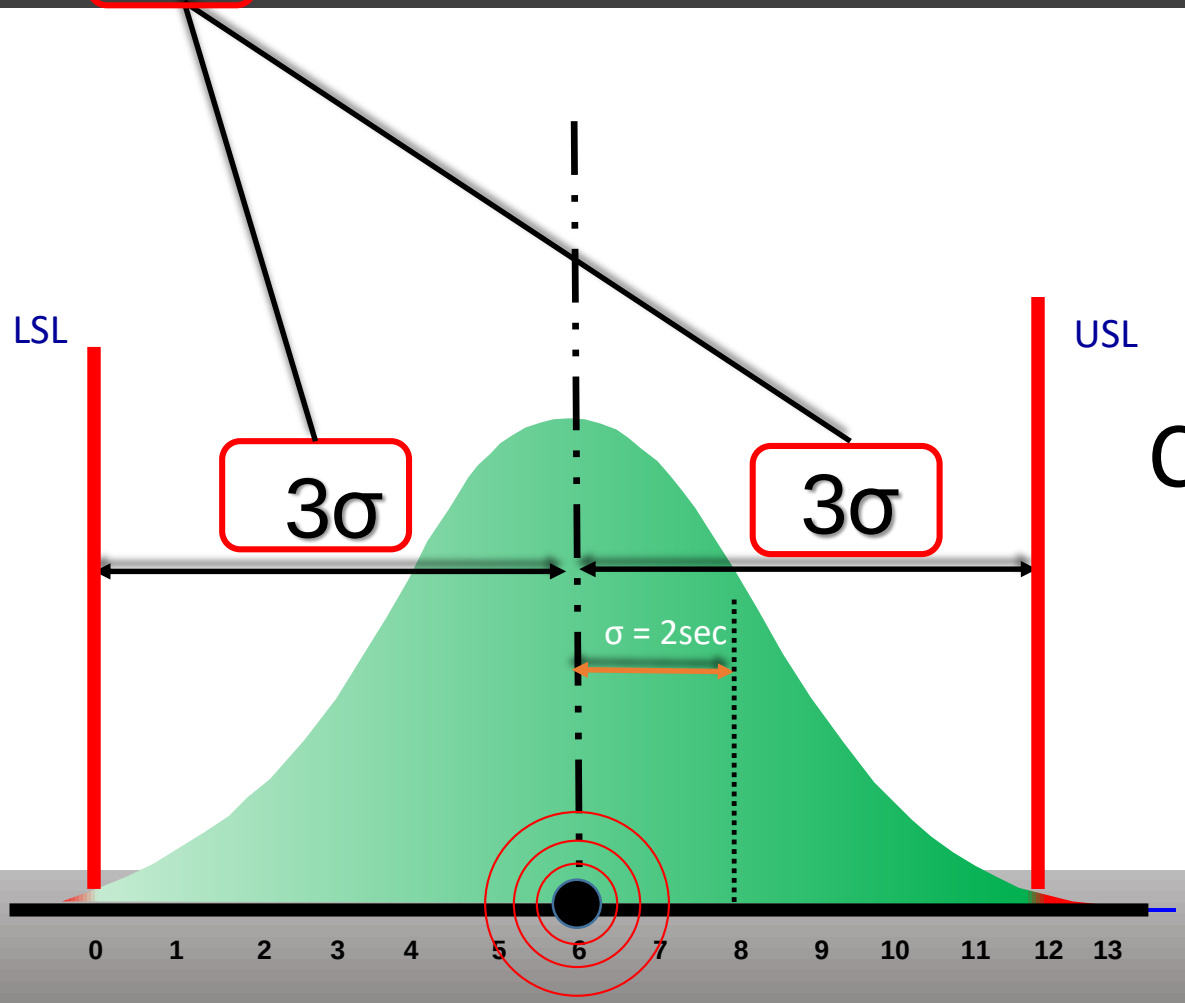
Capability to meet specs

3.4 DPMO



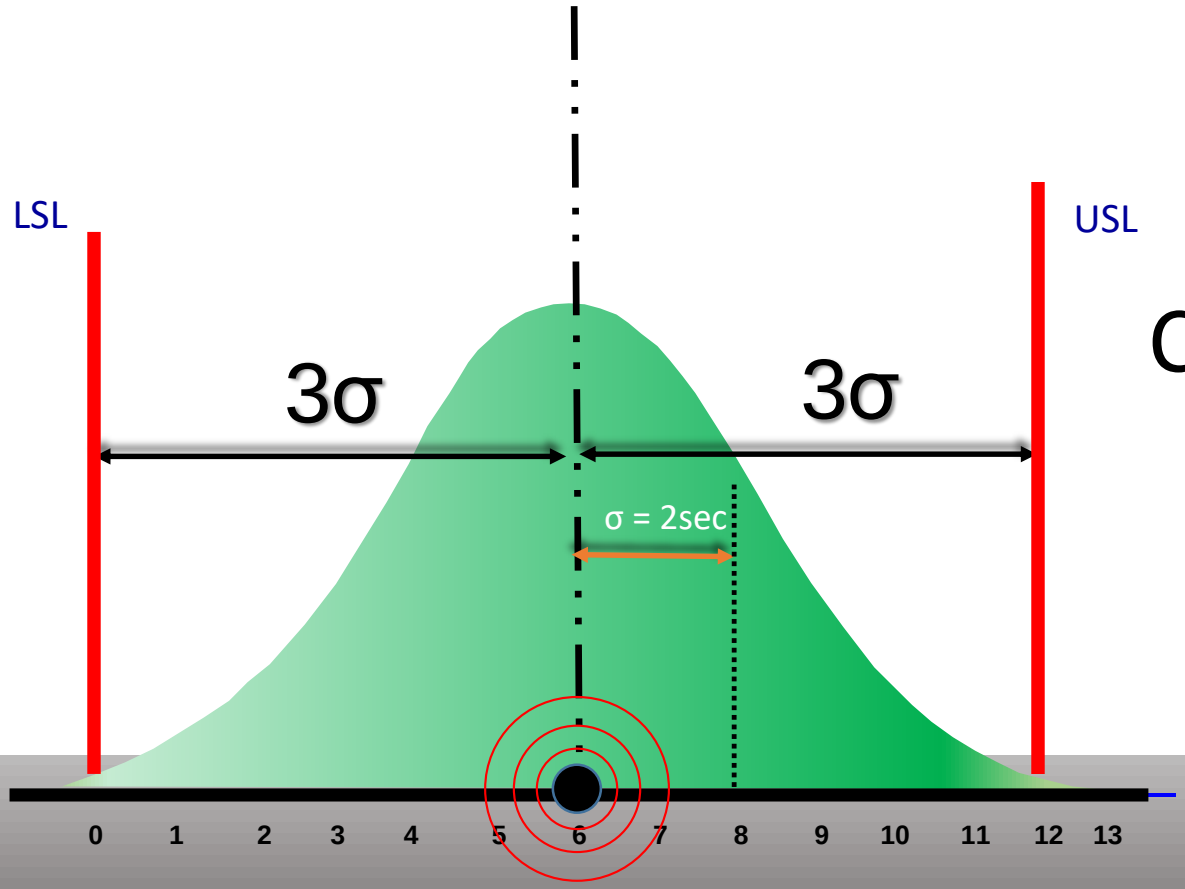
Performance w/shift

3σ PROCESS CAPABILITY



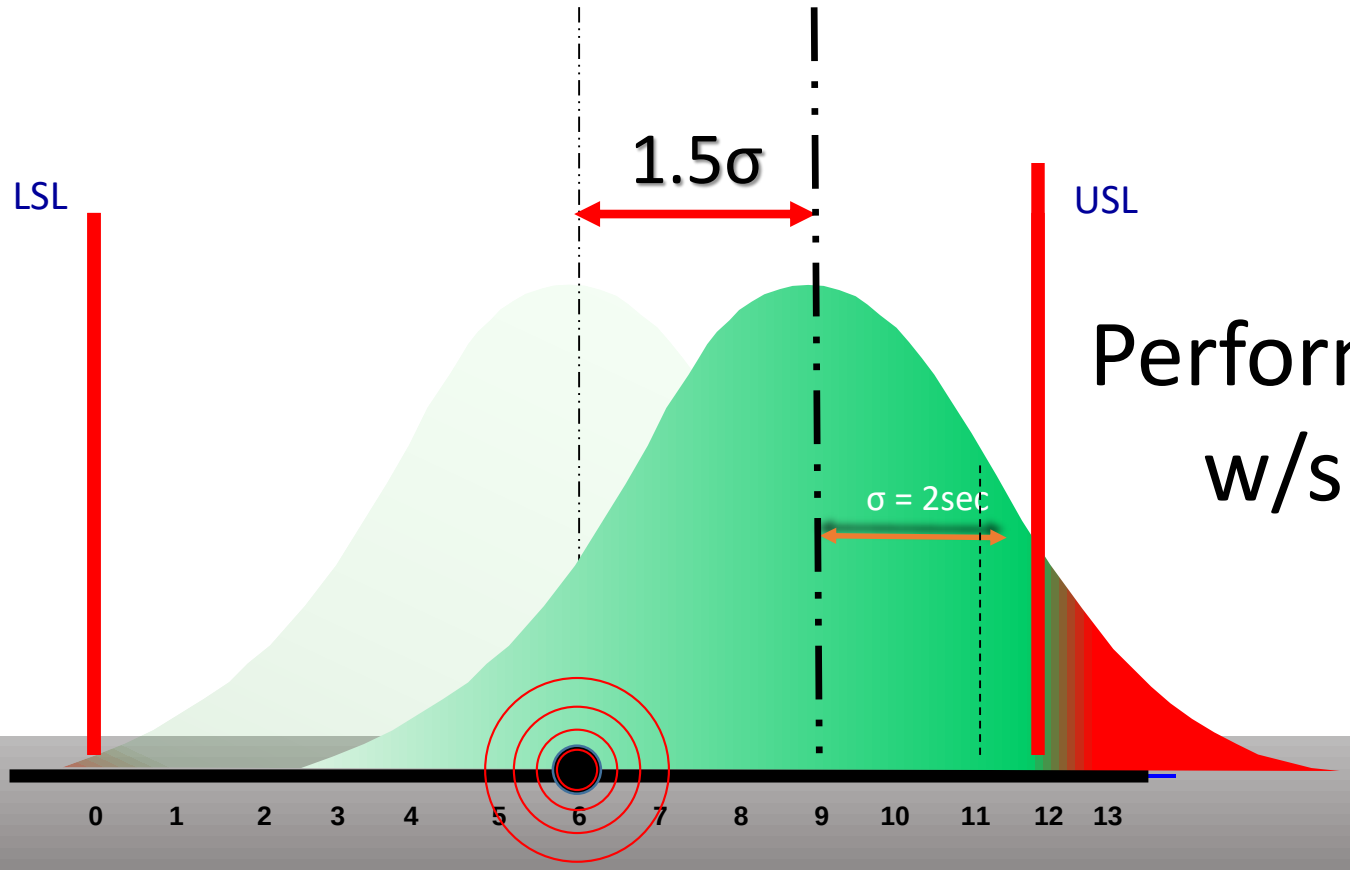
Capability to meet specs

2,700 DPMO



Capability to meet specs

69,000 DPMO

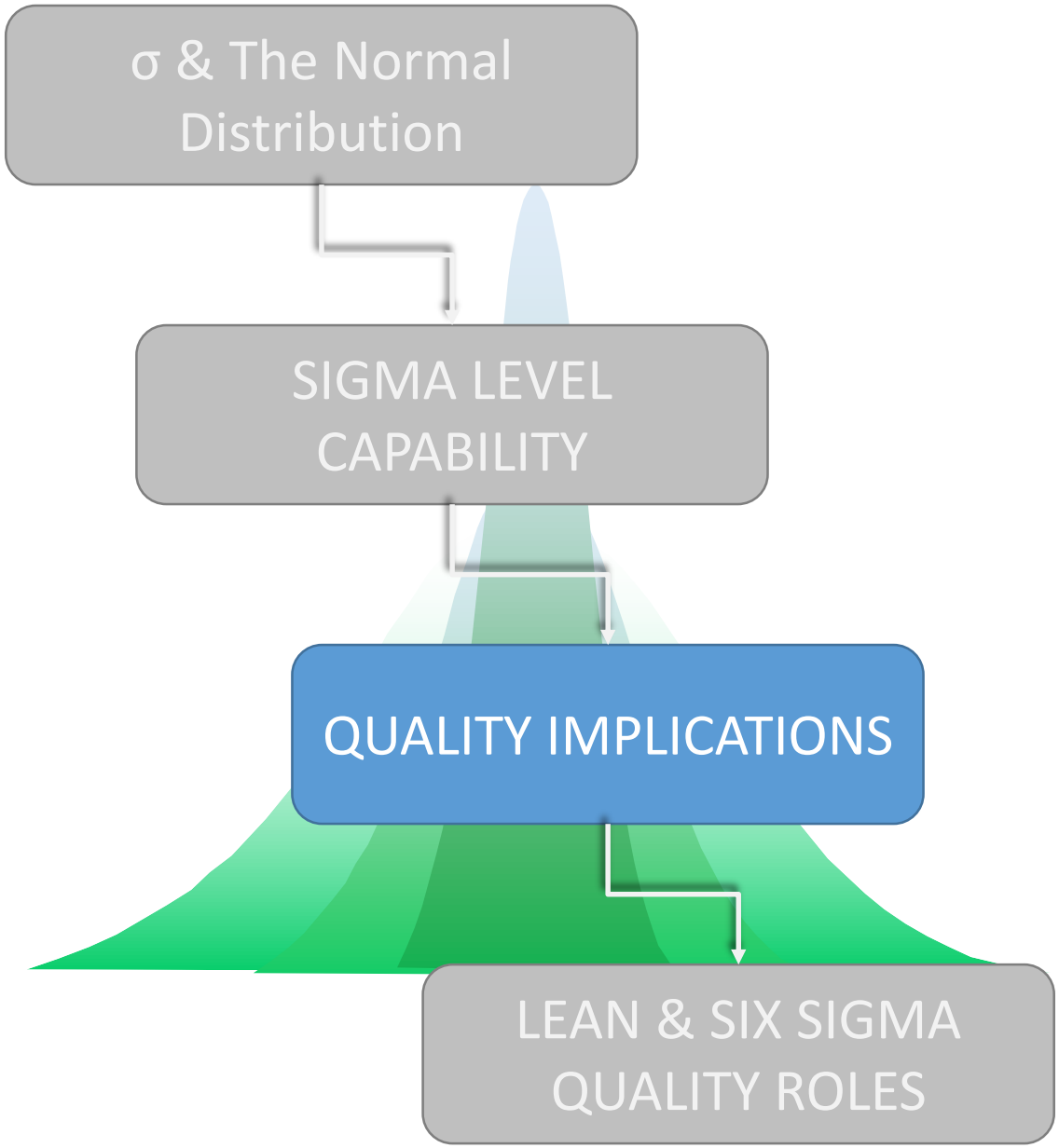


Performance w/shift

VARIATION –

Analysis/Reduction

SIX SIGMA
THEME 1



DEFECT RATE

3σ Process --69,000.0 DPMO

6σ Process --------- 3.4 DPMO

defects per million opportunities

FAILURE OPPORTUNITY

OUTCOME REQUIREMENT =

FAILURE OPPORTUNITY

DEFECT

A DEFECT =

AN UNFILLED REQUIREMENT

DEFECTIVE VS. DEFECTS

DEFECTIVE =

1 or MORE DEFECTS

QUESTIONS 6 & 7

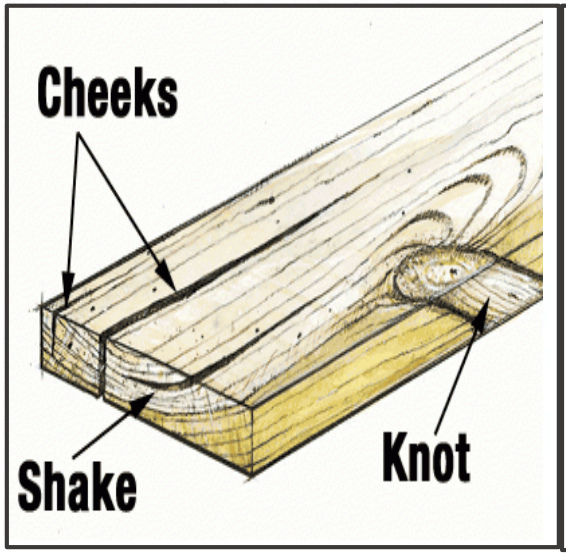
DEFECTS

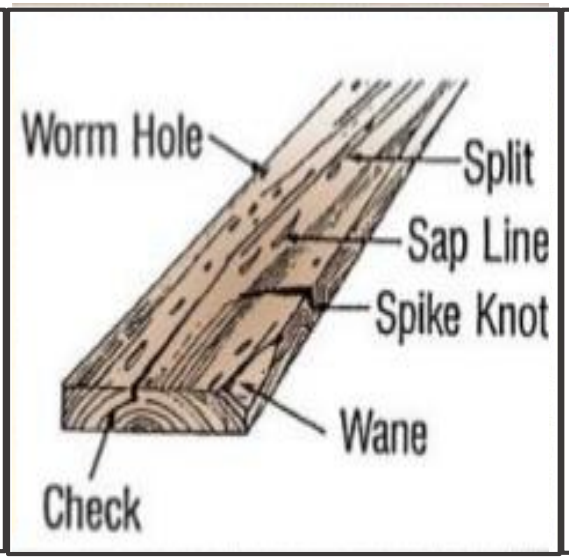
VS.

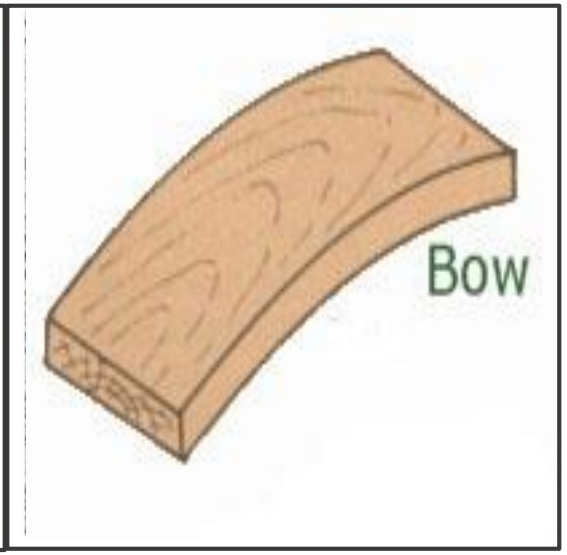
DEFECTIVES

Pass down your post-it notes if you raised your hand.

QUESTION 6 – DEFECT VS. DEFECTIVE







- NUMBER OF DEFECTS? _____
- NUMBER OF DEFECTIVES? _____

QUESTION 7 – DEFECT VS. DEFECTIVE

Shipment 1	Shipment 2	Shipment 2
• **On time** • **All items correct** • **No breakage**	• **On time** • **2 incorrect items** • **1 item broken**	• **Arrived late** • **All items correct** • **1 item broken**

- NUMBER OF DEFECTS? _____
- NUMBER OF DEFECTIVES? _____

FAILURE

OPPORTUNITIES

>2000

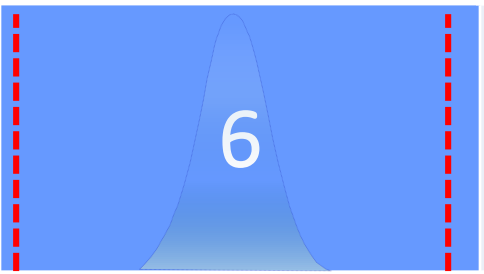
DEFECTIVES PER MILLION PRODUCED

Sigma Level	Failure Opportunities		
	1	10	1,000
6	**3.4**		

DEFECTIVES PER MILLION PRODUCED

Sigma Level	Failure Opportunities		
	1	10	1,000
6	3.4	**34**	

DEFECTIVES PER MILLION PRODUCED

Sigma Level	Failure Opportunities		
	1	10	1,000
 6	3.4	34	**3,400**

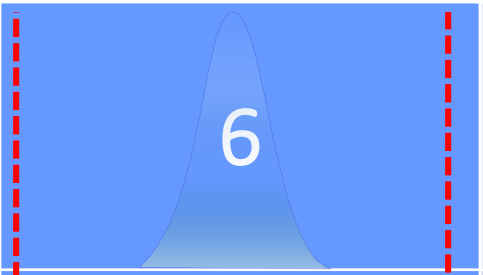
DEFECTIVES PER MILLION PRODUCED

Sigma Level	Failure Opportunities		
	1	10	1,000
6	3.4	34	3,400
3	**67,000**		

DEFECTIVES PER MILLION PRODUCED

Sigma Level	Failure Opportunities		
	1	10	1,000
6	3.4	34	3,400
3	67,000	**500,000**	

DEFECTIVES PER MILLION PRODUCED

Sigma Level	Failure Opportunities		
	1	10	1,000
 6	3.4	34	3,400
3	67,000	500,000	**1,000,000**

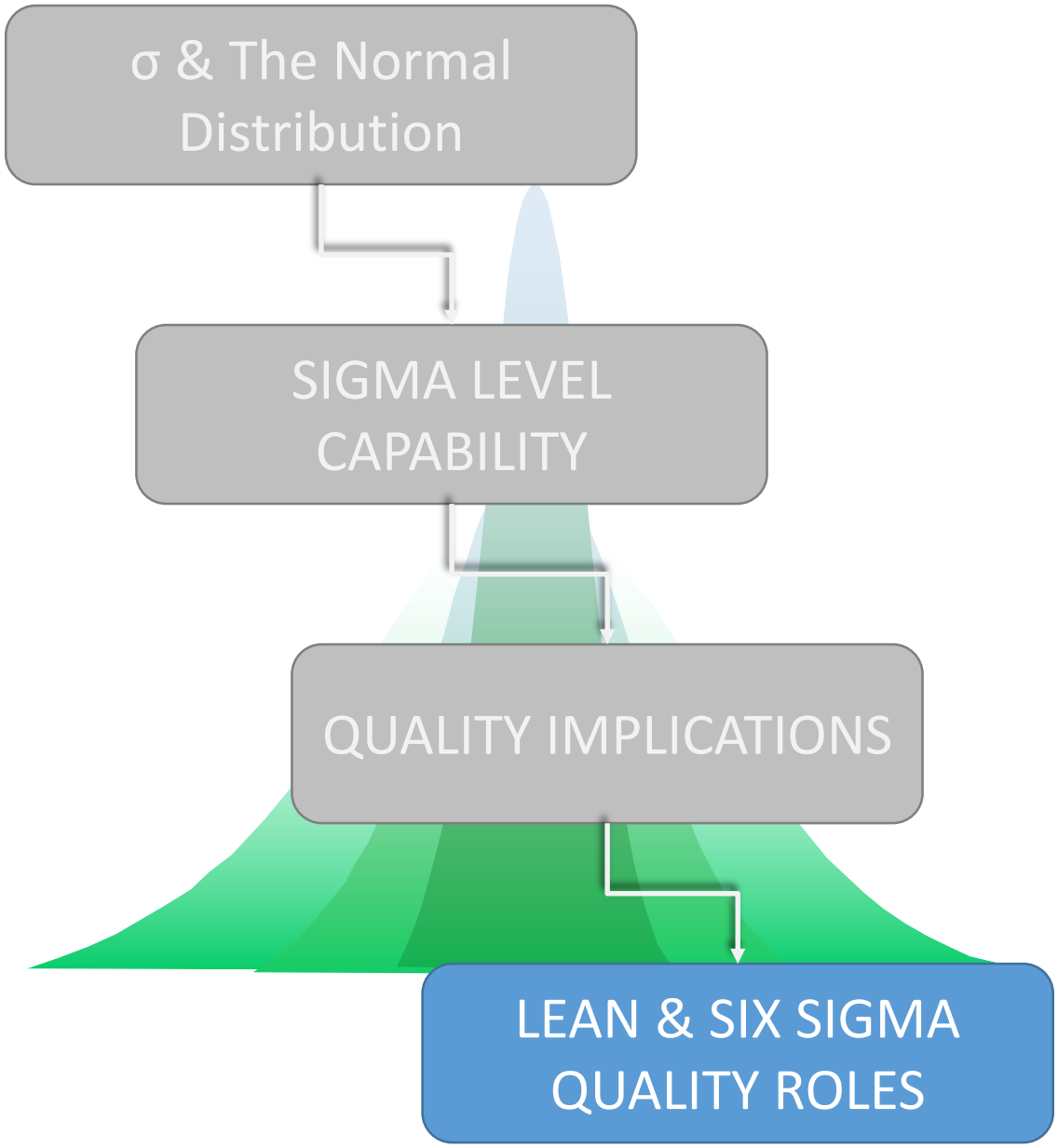
PERCENT DEFECTIVES PRODUCED

Sigma Level	Failure Opportunities		
	1	10	1,000
6	0.0003%	**0.003%**	**0.34%**
3	6.7%	**50%**	**100%**

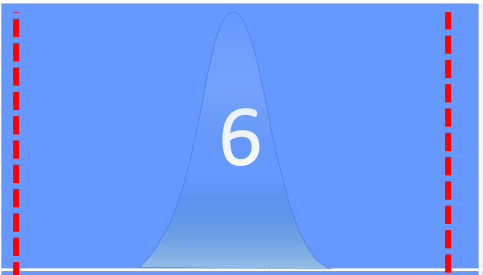
VARIATION –

Analysis/Reduction

SIX SIGMA
THEME 1



DEFECTIVES PER MILLION PRODUCED

Sigma Level	Failure Opportunities		
	1	10	1,000
 6	3.4	34	**3,400**
3	67,000	500,000	**1,000,000**

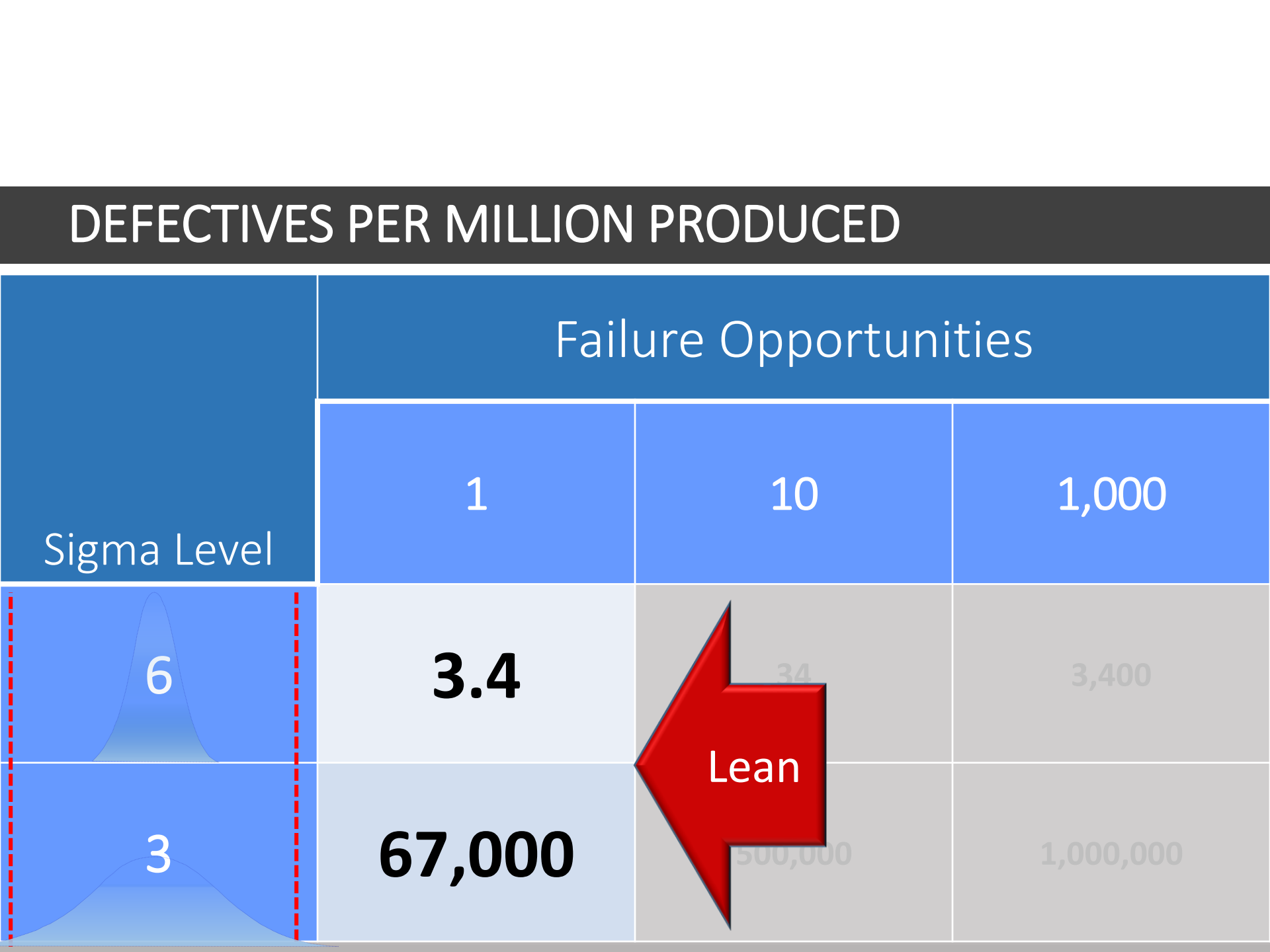
DEFECTIVES PER MILLION PRODUCED

Sigma Level	Failure Opportunities		
	1	10	1,000
6	3.4	**34**	3,400
3	67,000	**500,000**	2,000,000

Lean

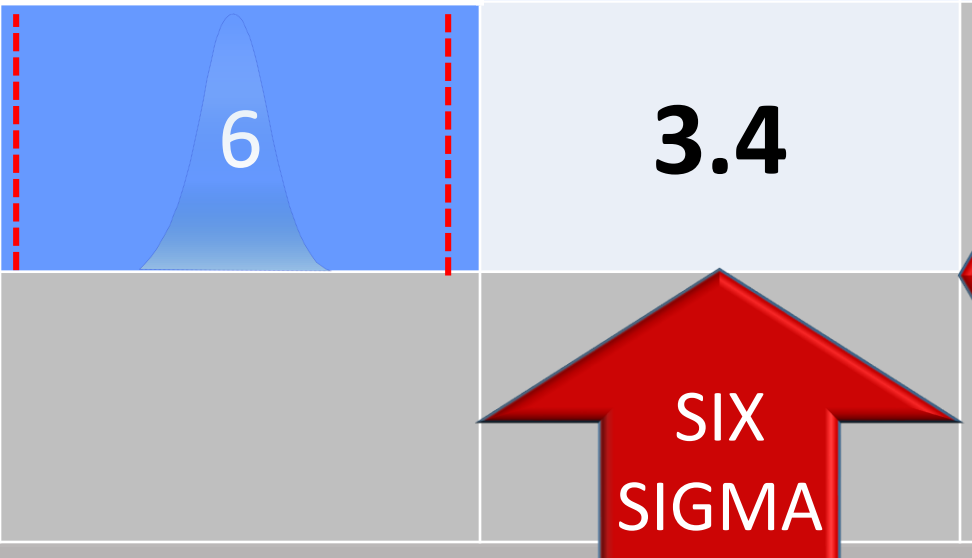
DEFECTIVES PER MILLION PRODUCED

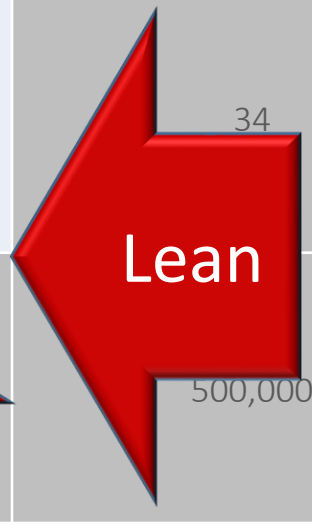
Sigma Level	Failure Opportunities		
	1	10	1,000
6	**3.4**	34	3,400
3	**67,000**	500,000	1,000,000



DEFECTIVES PER MILLION PRODUCED

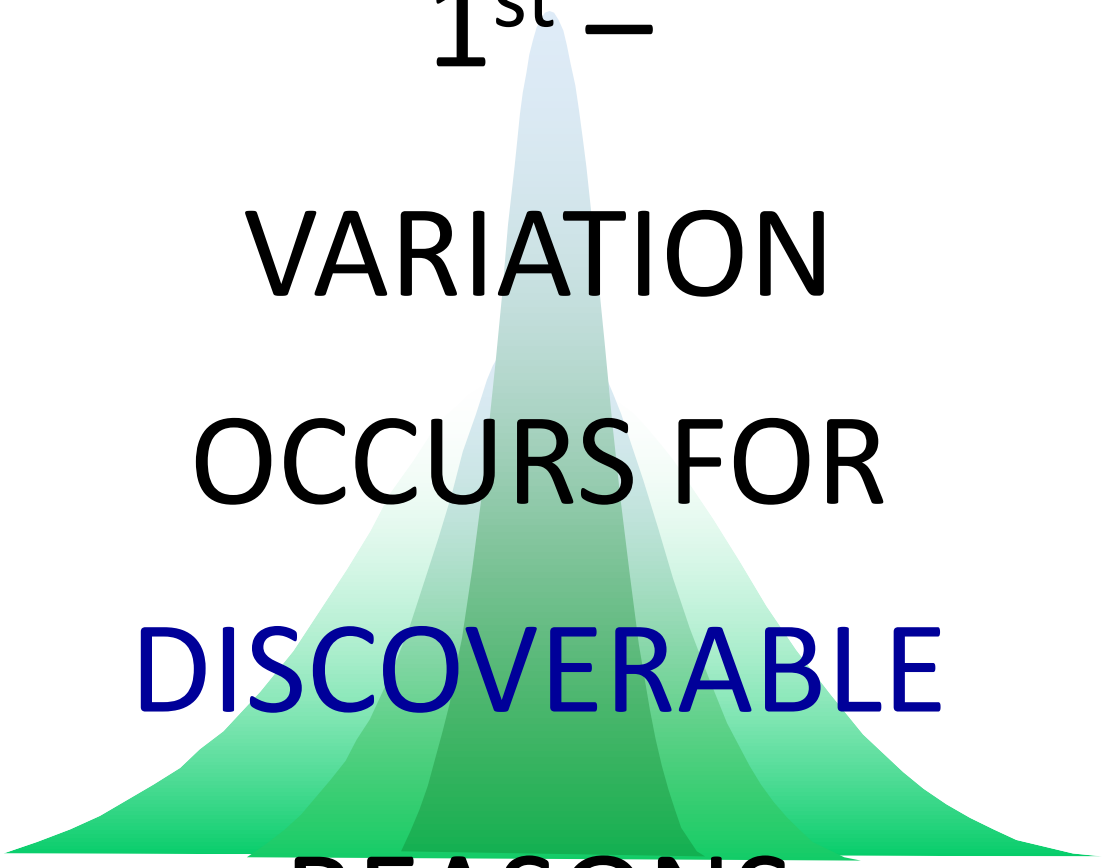
Sigma Level	Failure Opportunities		
	1	10	1,000
6	**3.4**	34	3,400
		500,000	1,000,000





Y = f(x)

SIX SIGMA
Theme 2
part 1/2



1st –

VARIATION

OCCURS FOR

DISCOVERABLE

REASONS

$Y = f(x_1, x_2, ---x_i)$

SIX SIGMA
Theme 2
part 1/2

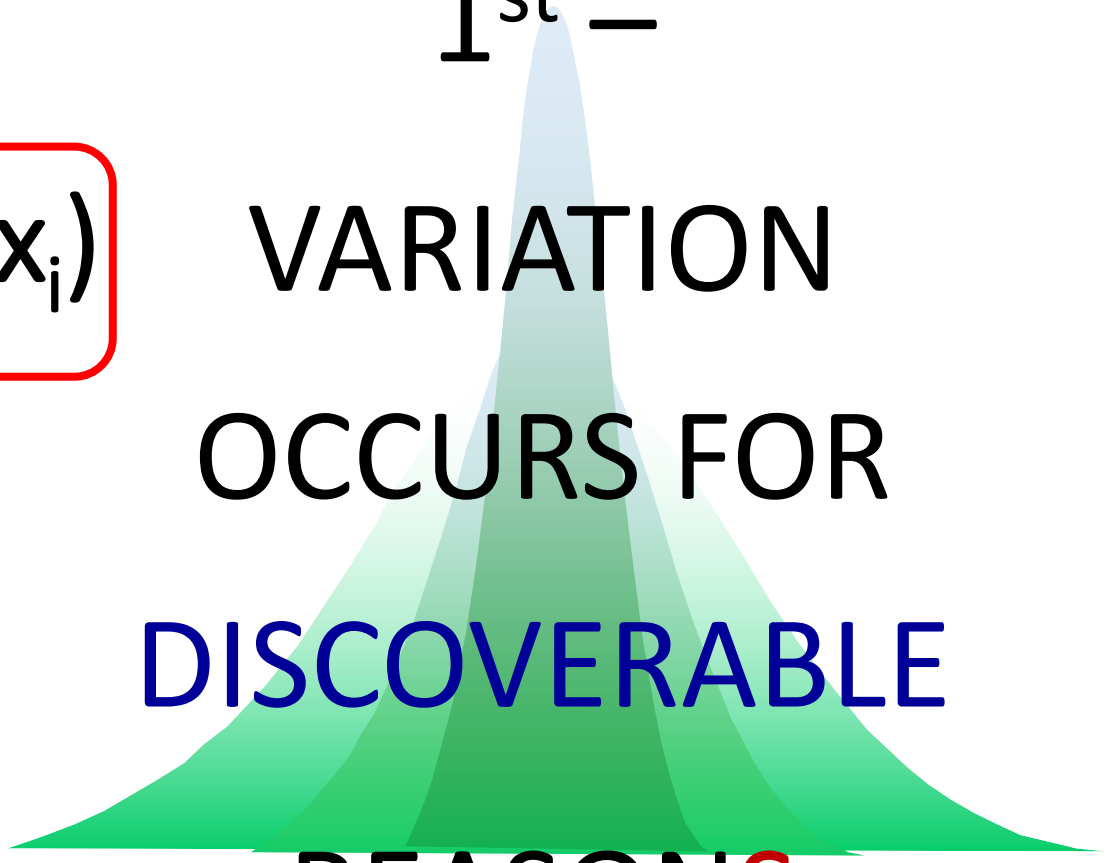
1st –

VARIATION

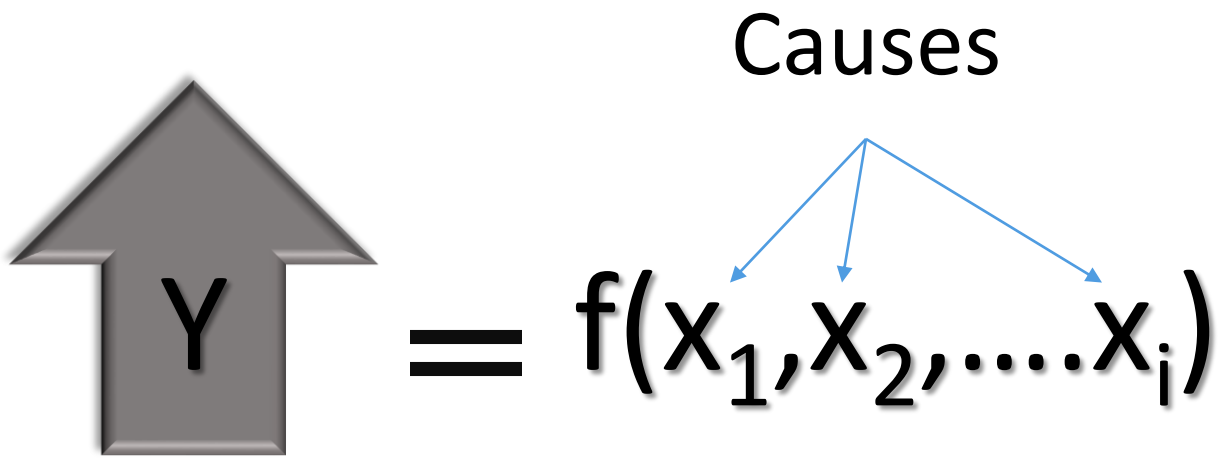
OCCURS FOR

DISCOVERABLE

REASONS

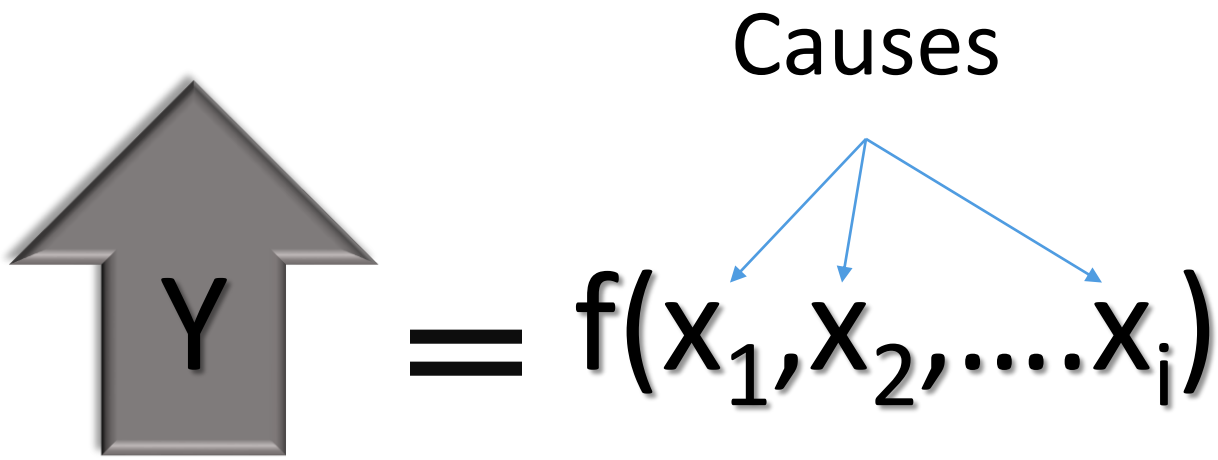


SIX SIGMA THEME 2 – part 1



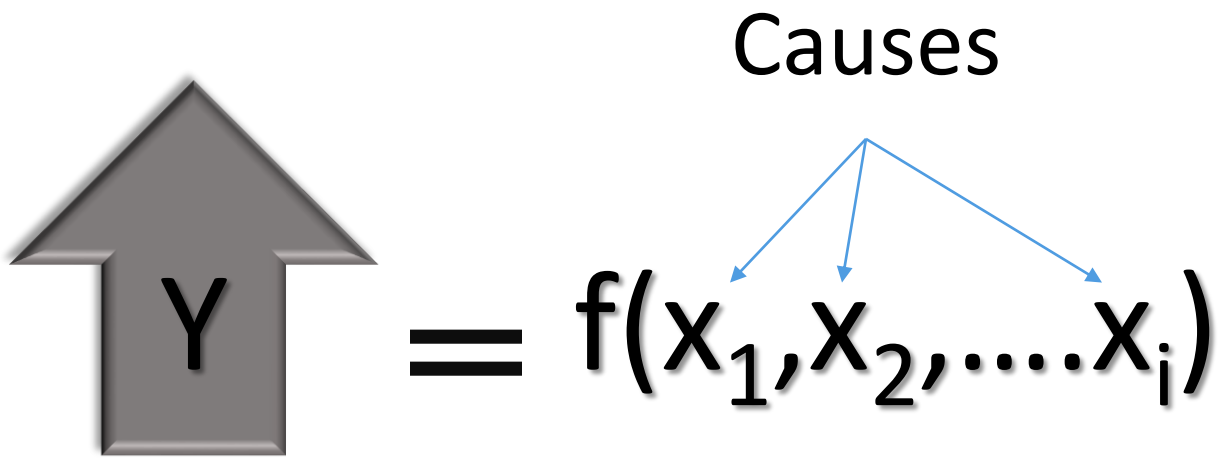
Net Profits

SIX SIGMA THEME 2 – part 1



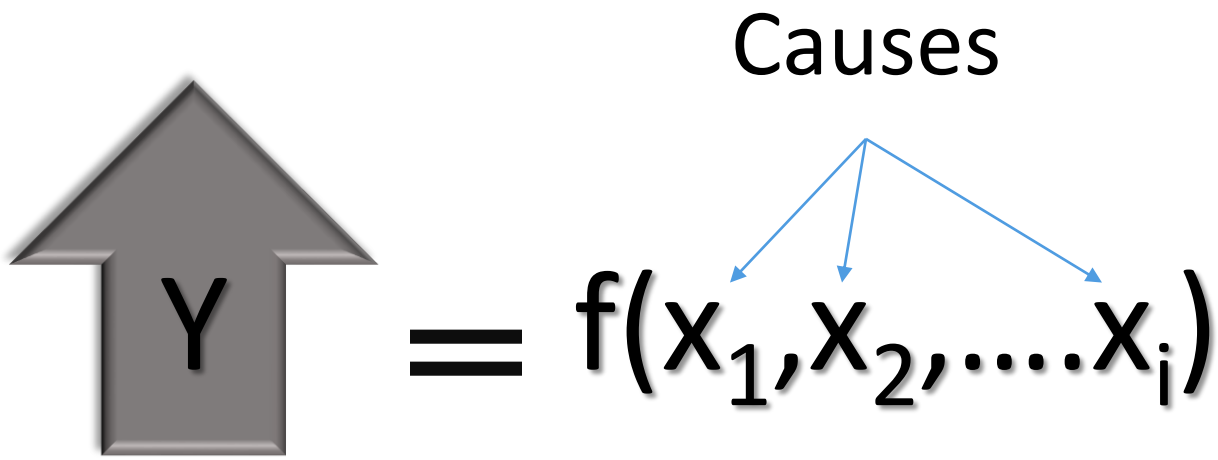
Customer Loyalty

SIX SIGMA THEME 2 – part 1



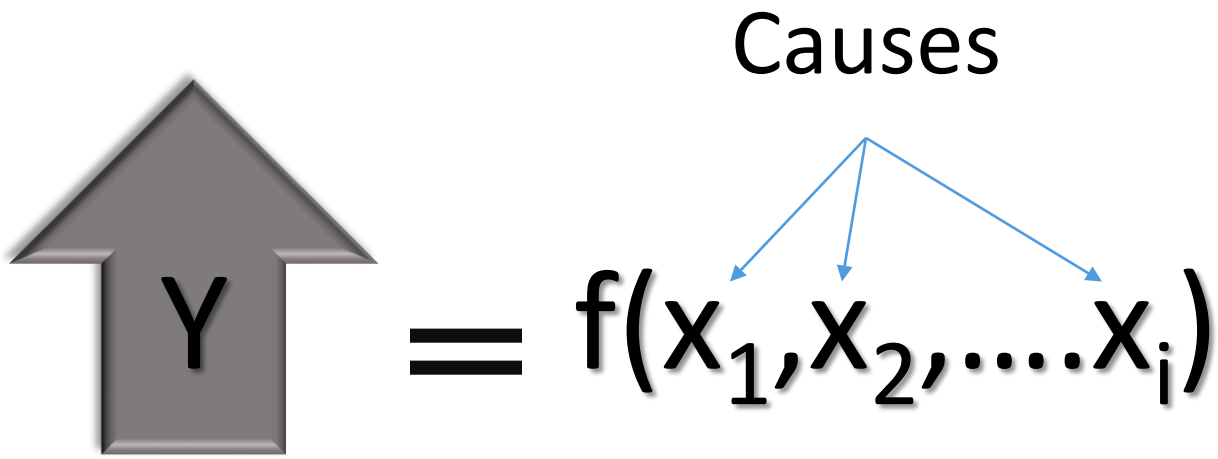
Productivity

SIX SIGMA THEME 2 – part 1



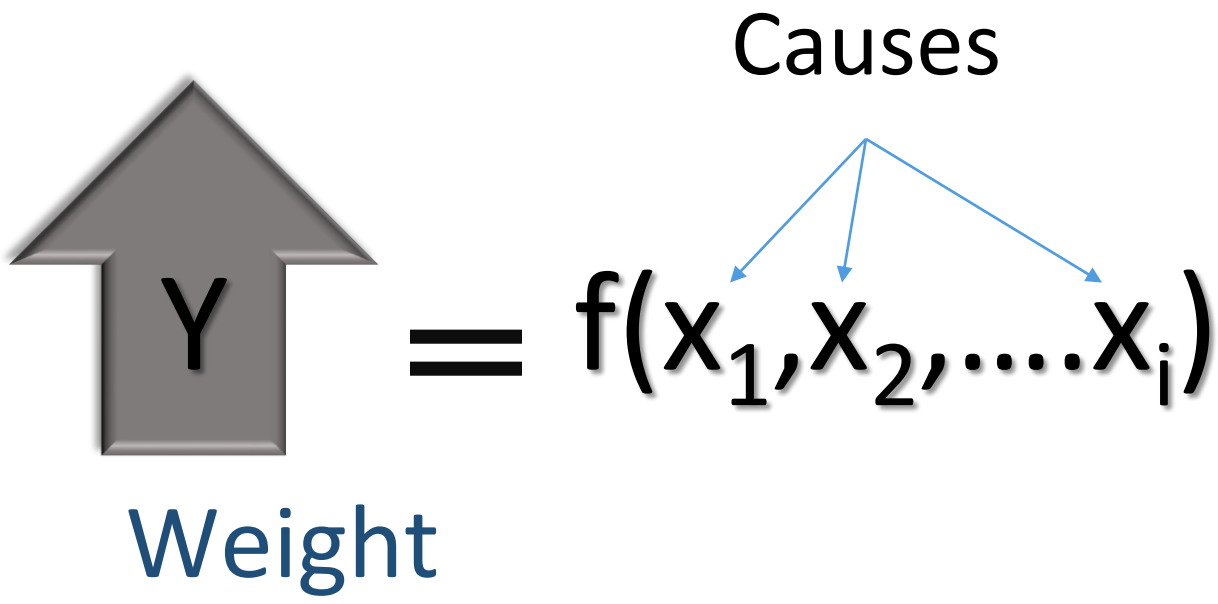
Time to Order

SIX SIGMA THEME 2 – part 1

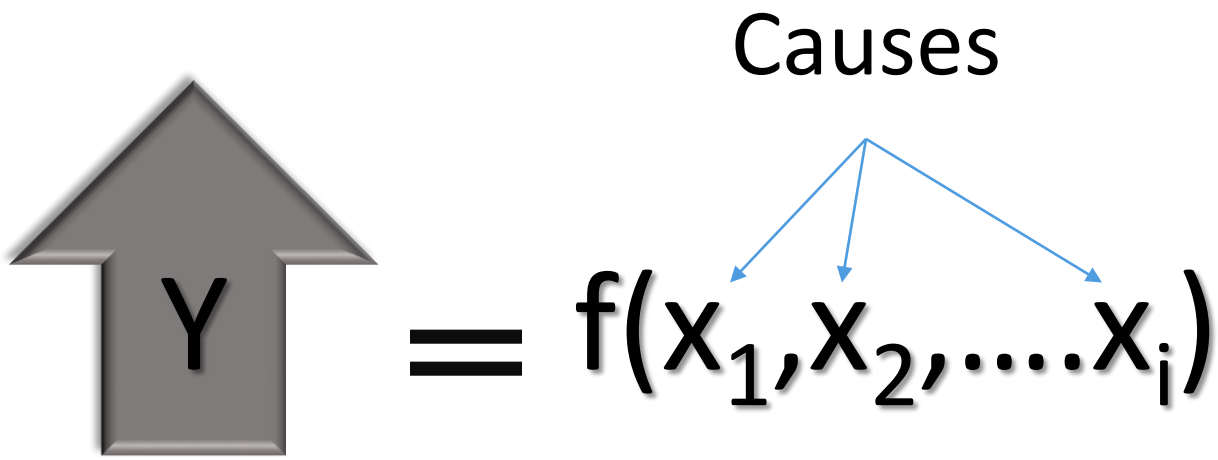


Dimensions

SIX SIGMA THEME 2 – part 1

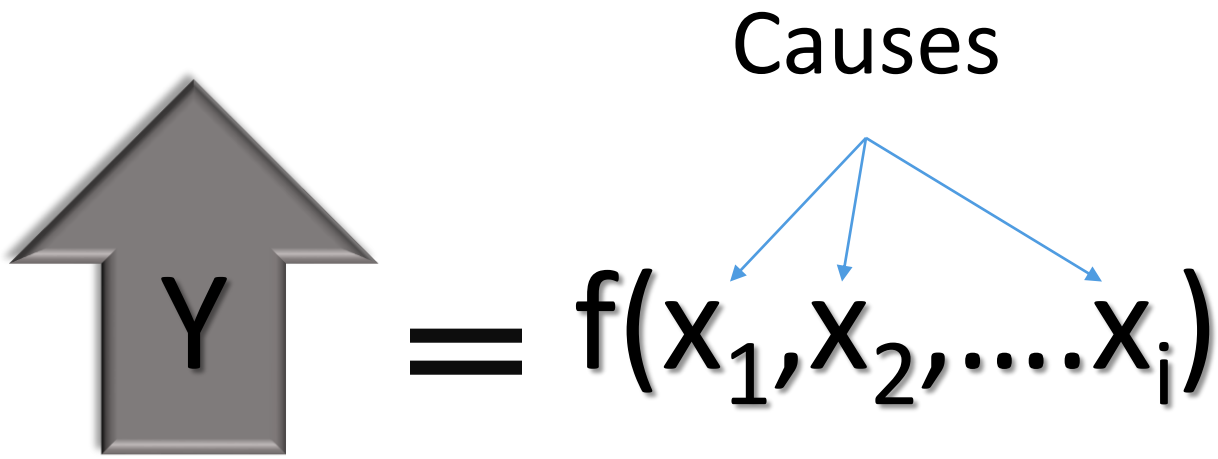


SIX SIGMA THEME 2 – part 1



Tensile Strength

SIX SIGMA THEME 2 – part 1

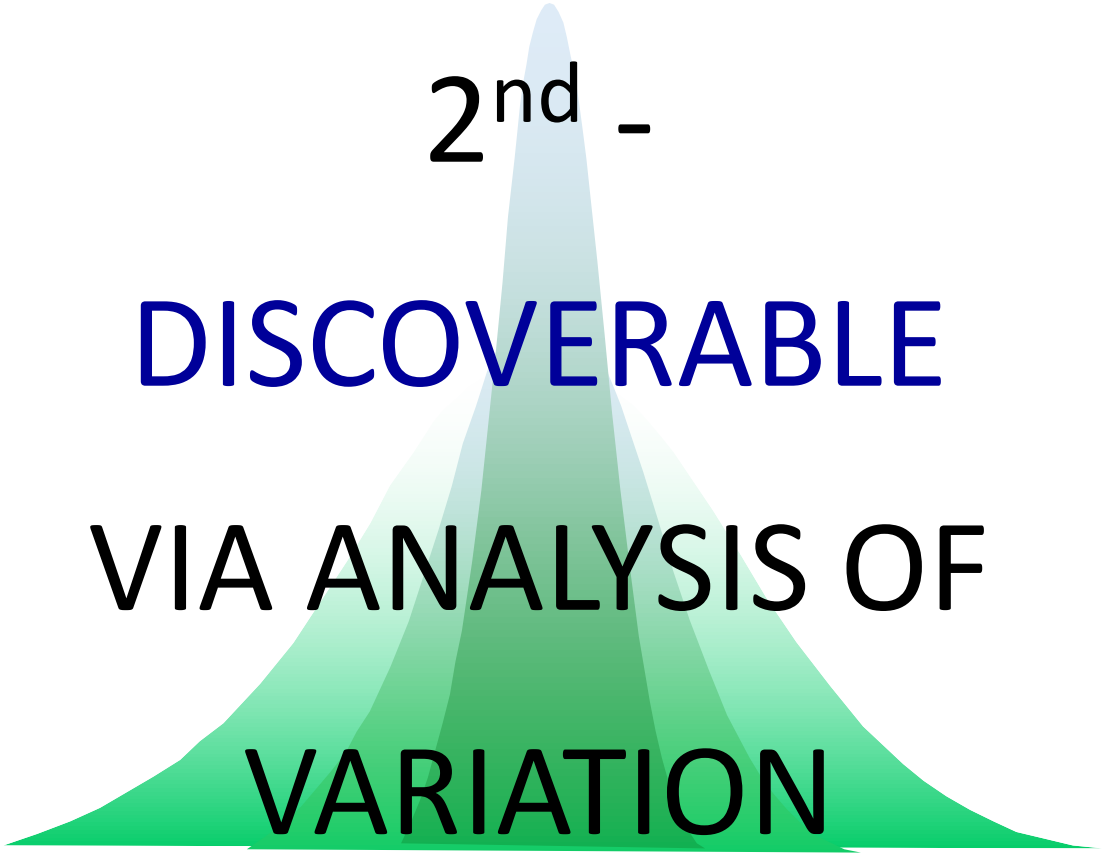


Measurement Precision

$Y = f(X)$

SIX SIGMA
Theme 2
part 2/2

2nd – DISCOVERABLE VIA ANALYSIS OF VARIATION

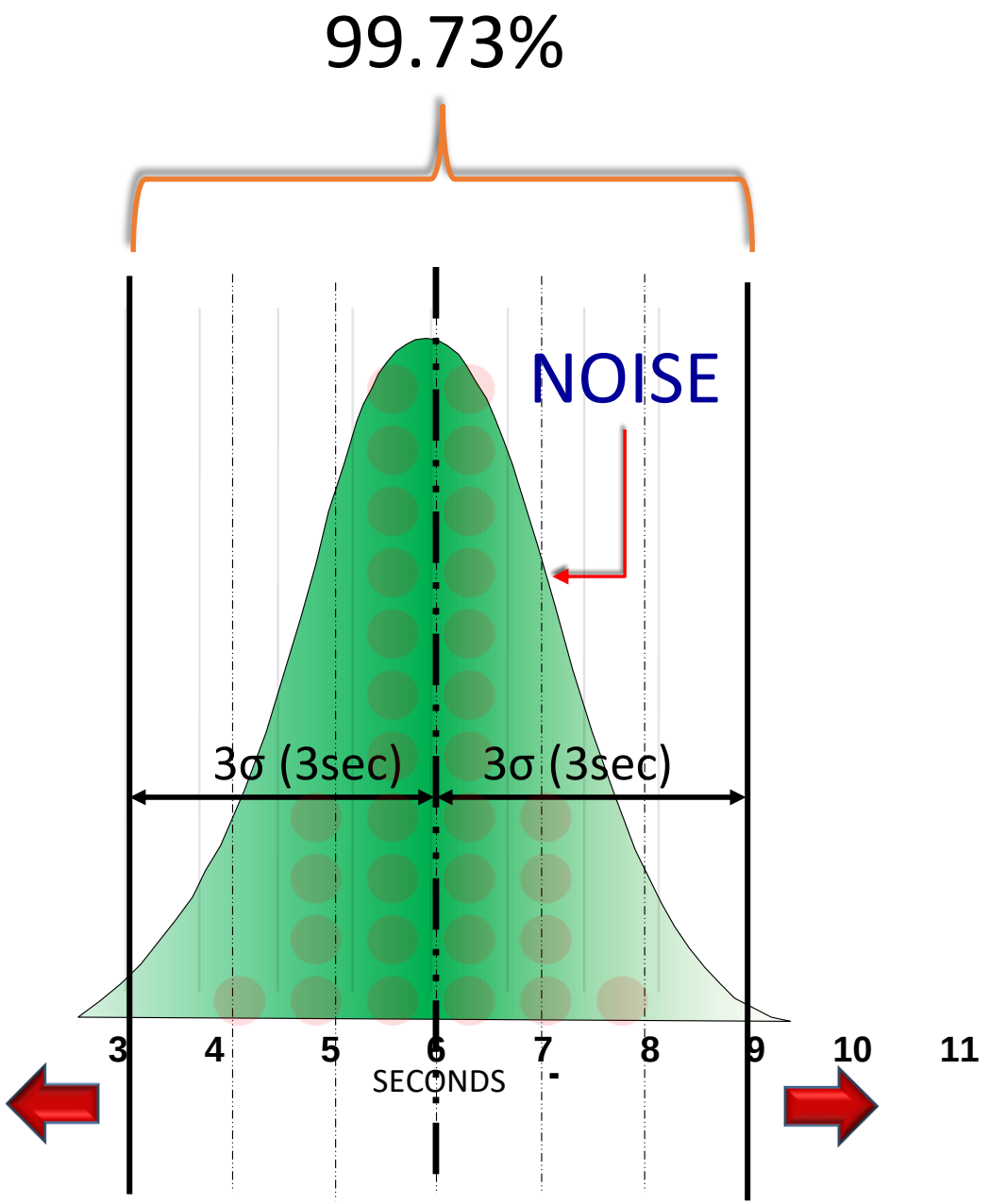


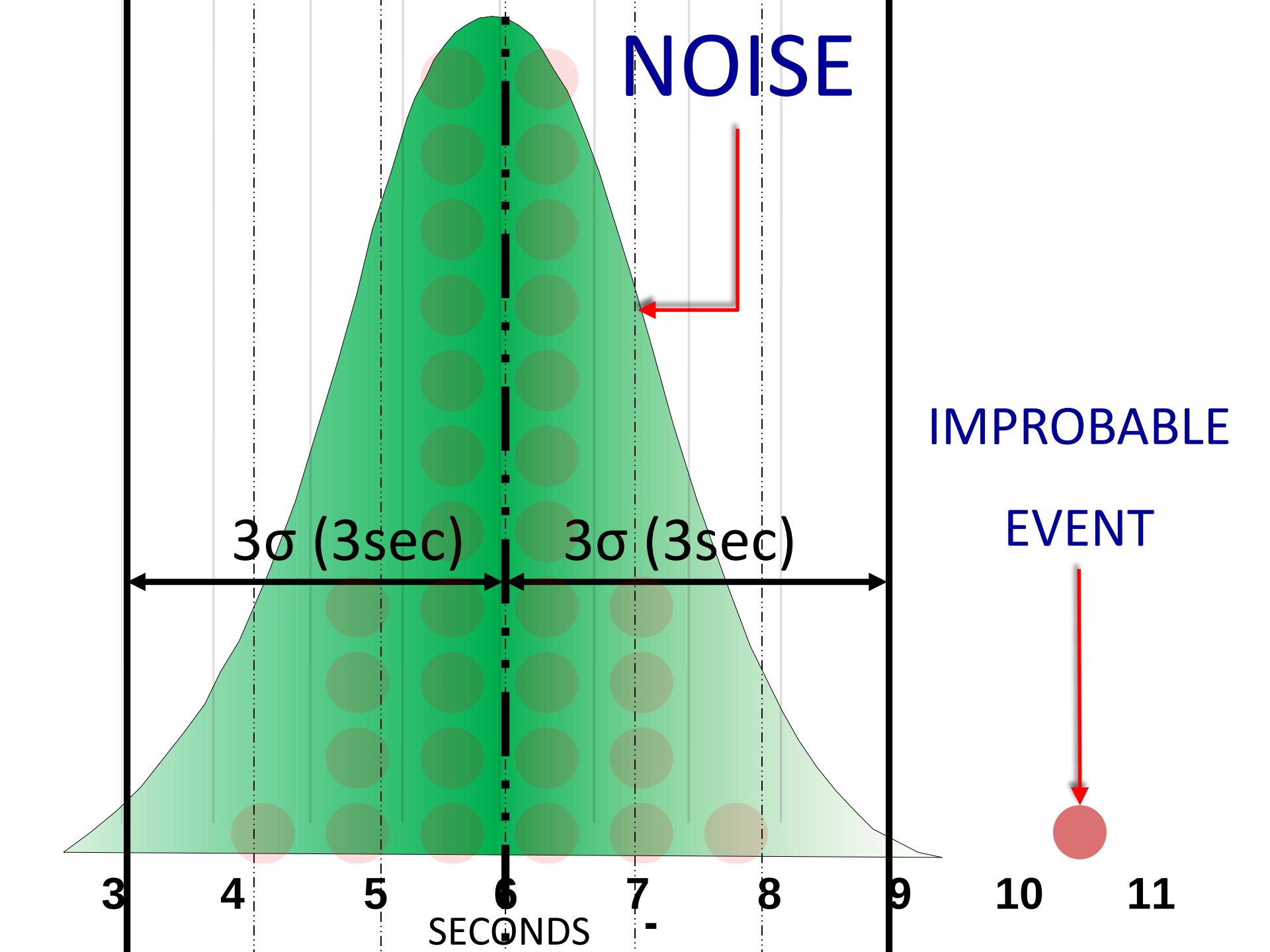
BEYOND 3 SIGMA LIMITS

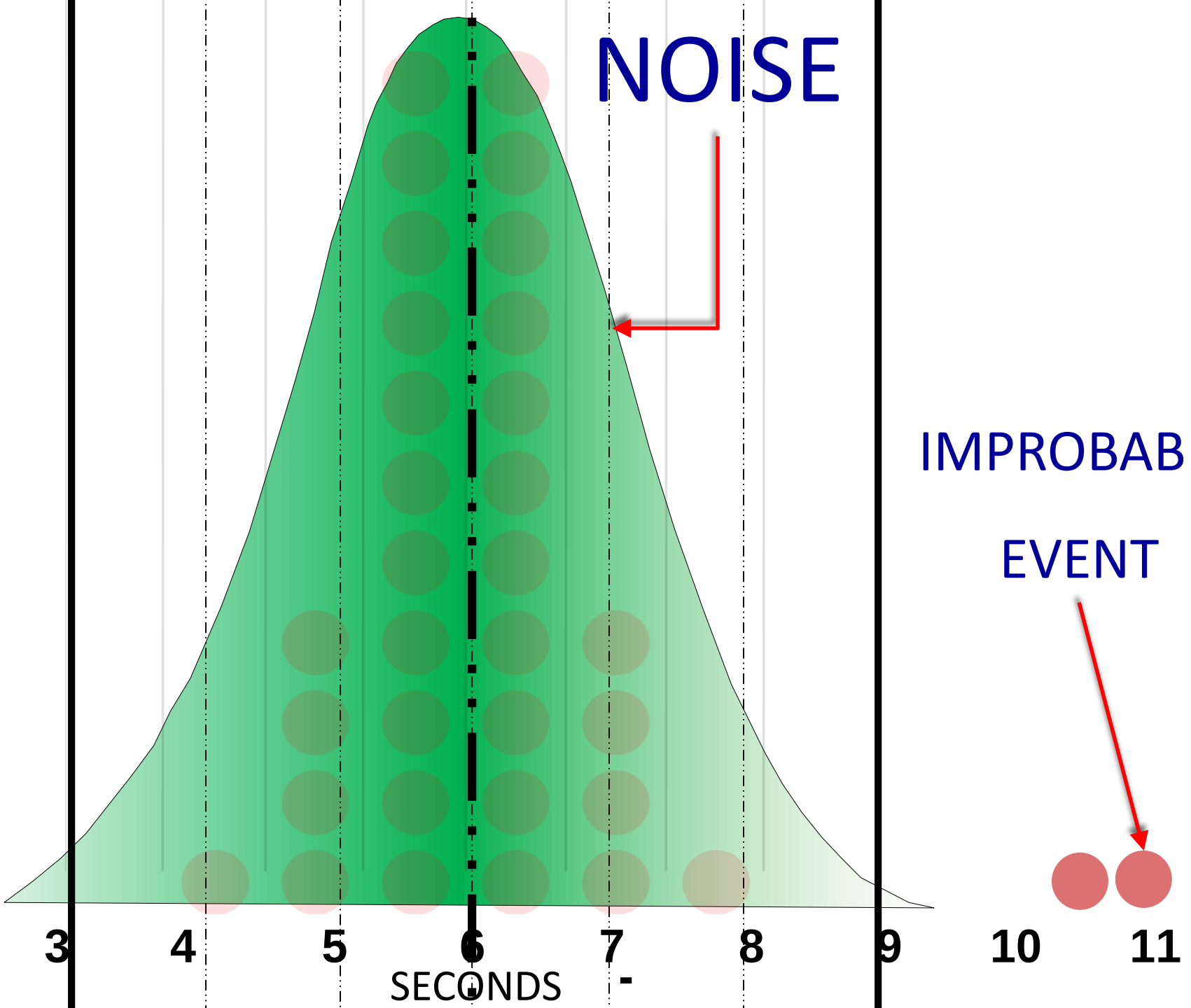
100%

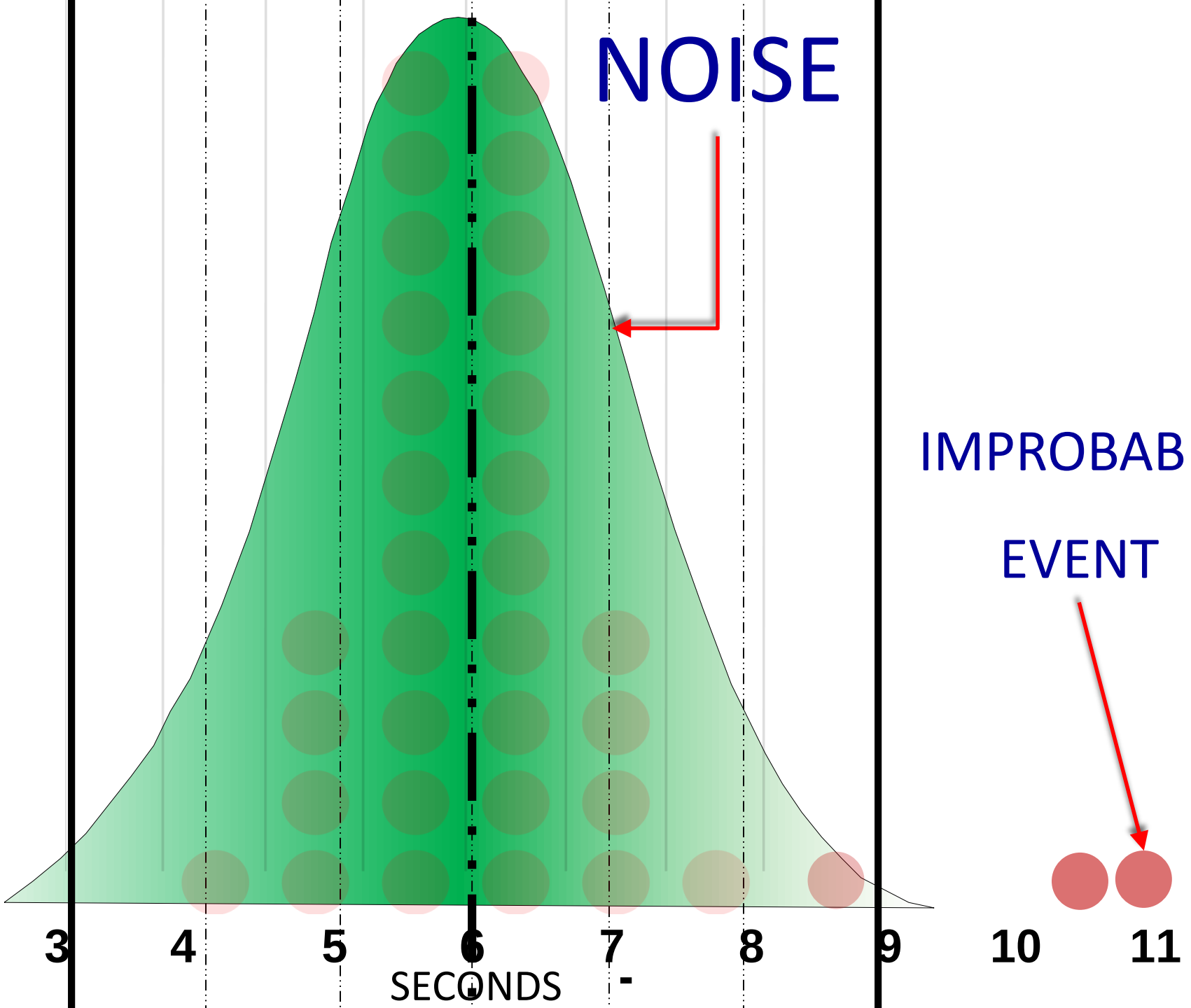
- 99.73%

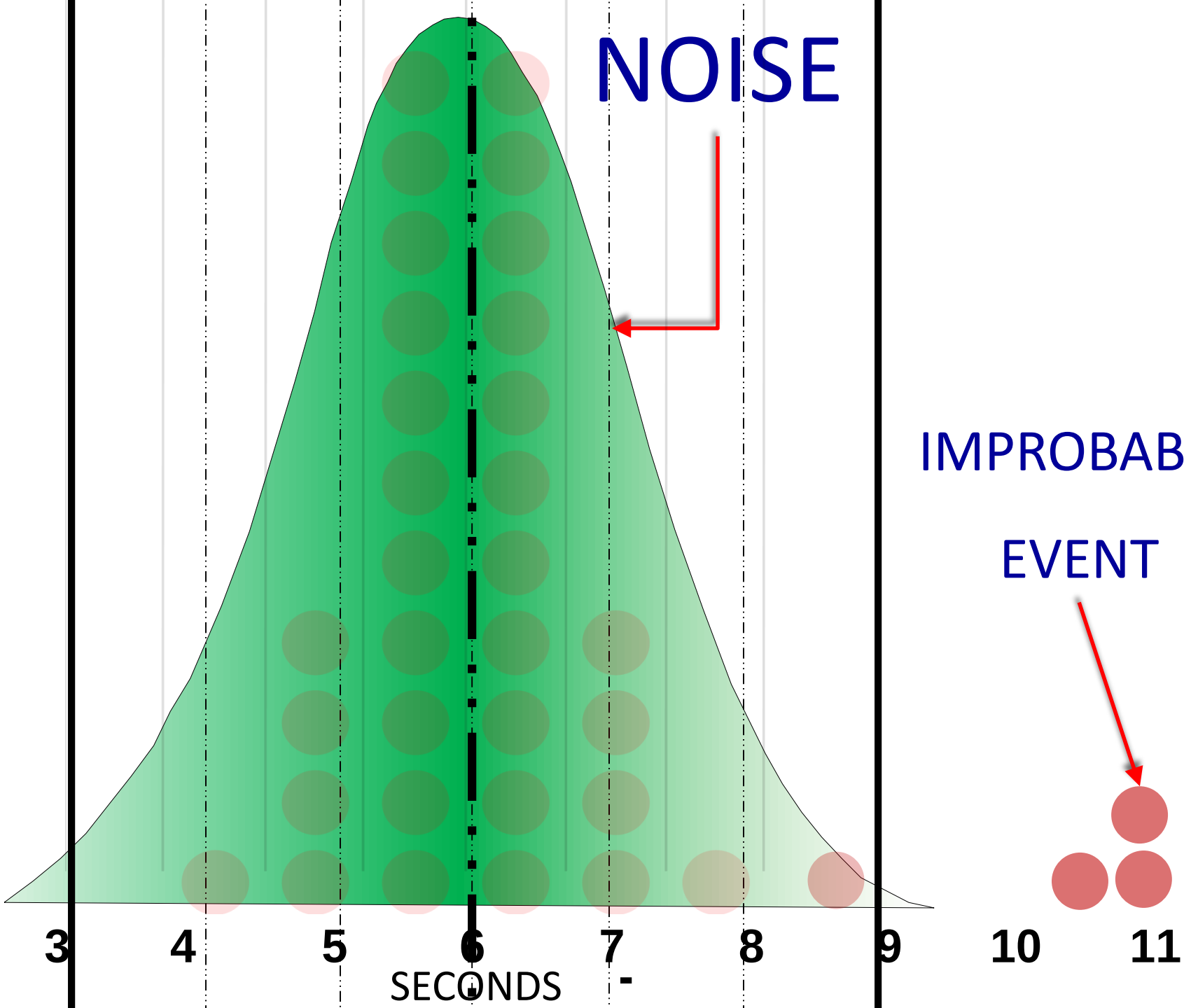
0.27%

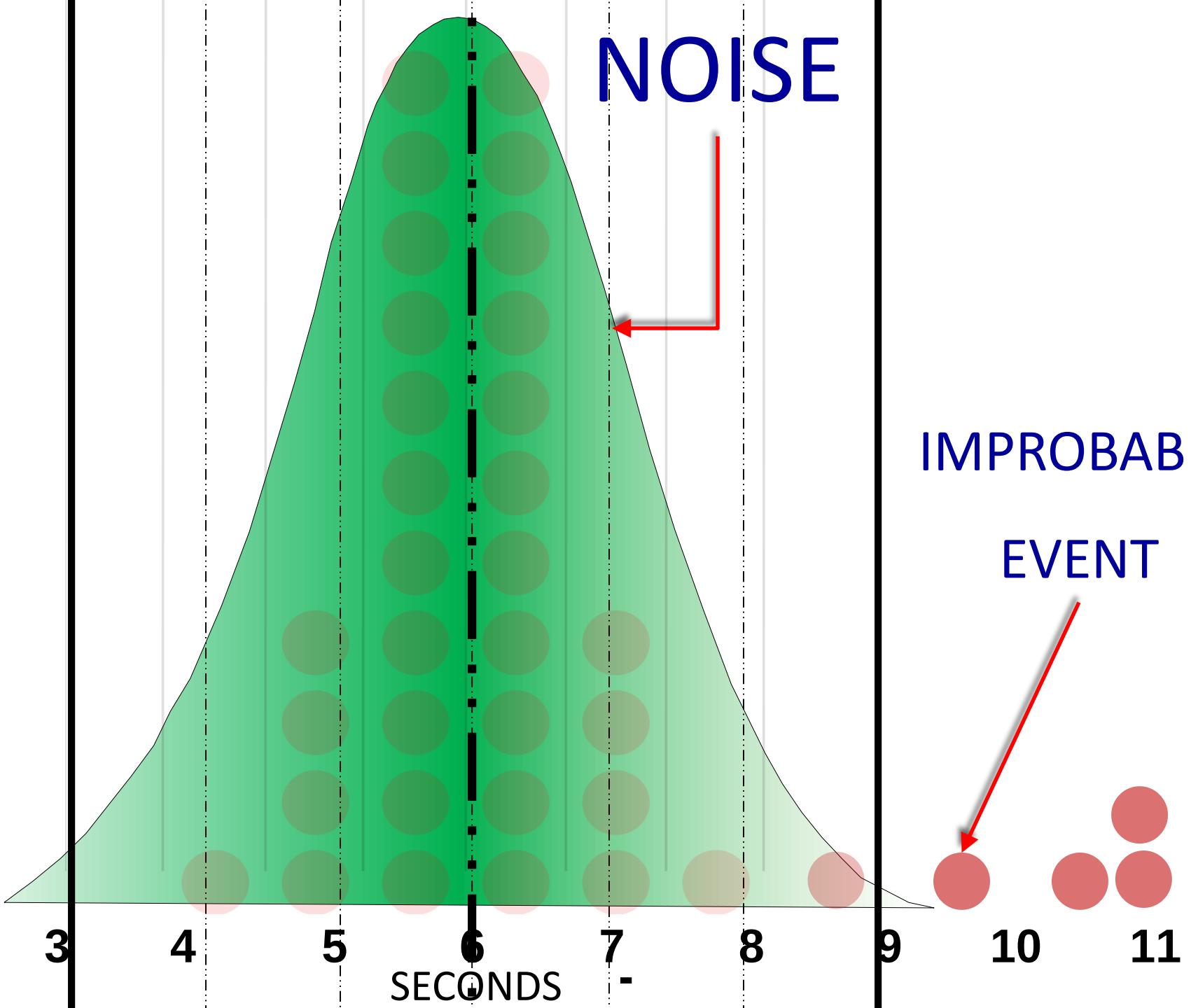


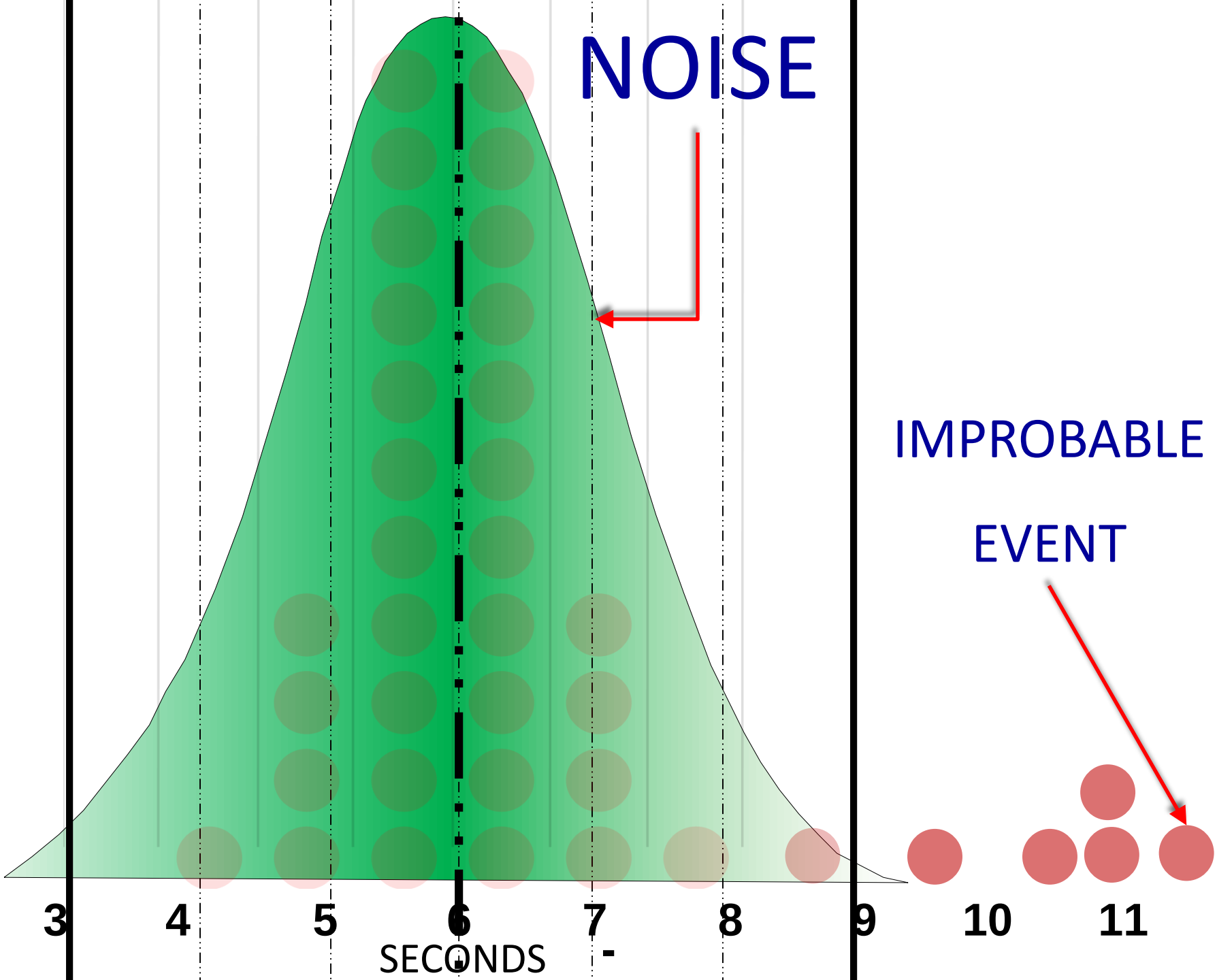

NOISE
IMPROBABLE
EVENT
3σ (3sec)
3σ (3sec)
3
4
5
6
7
8
9
10
11
SECONDS

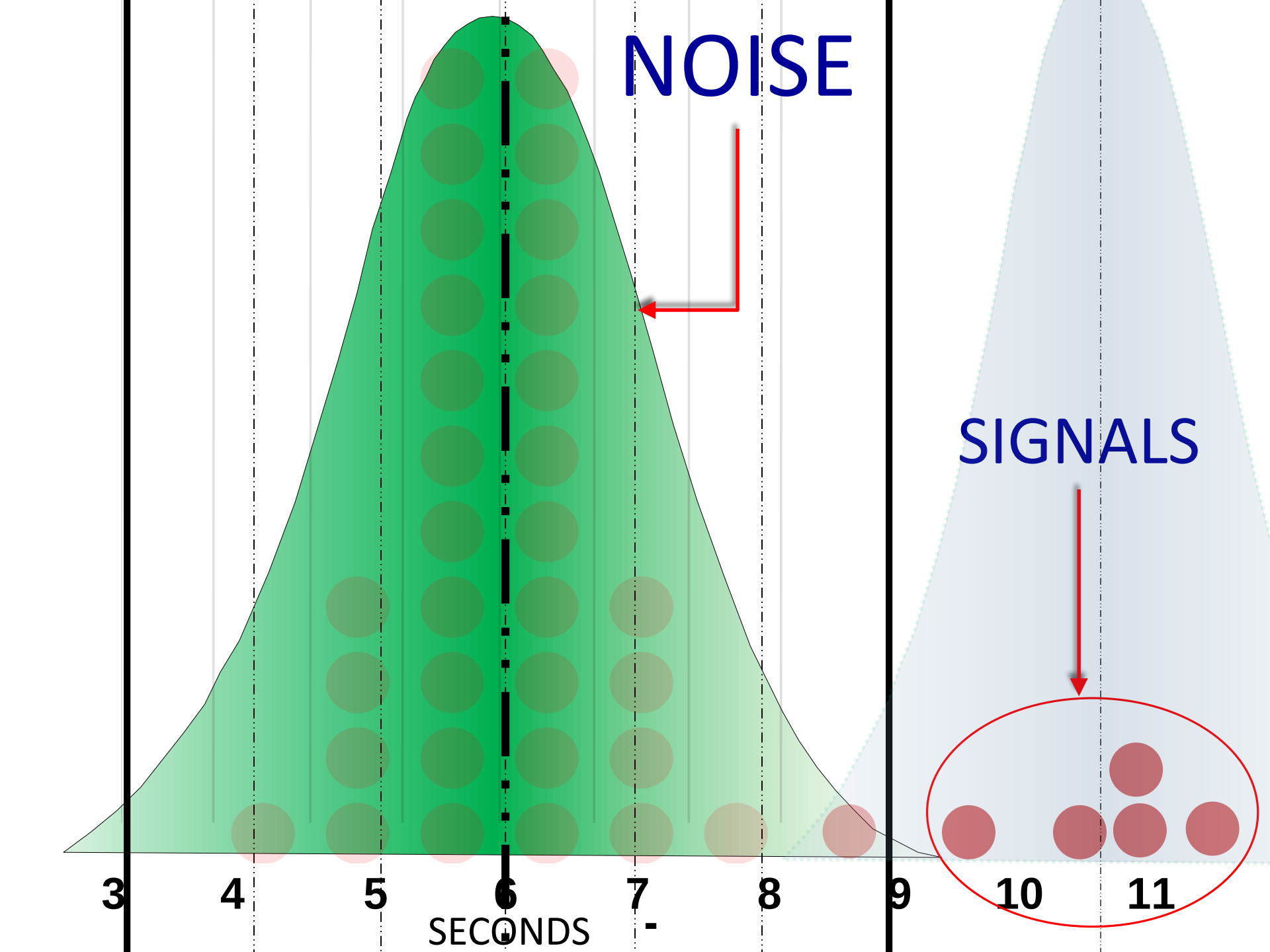

NOISE
IMPROBABLE
EVENT
3
4
5
6
7
8
9
10
11
SECONDS

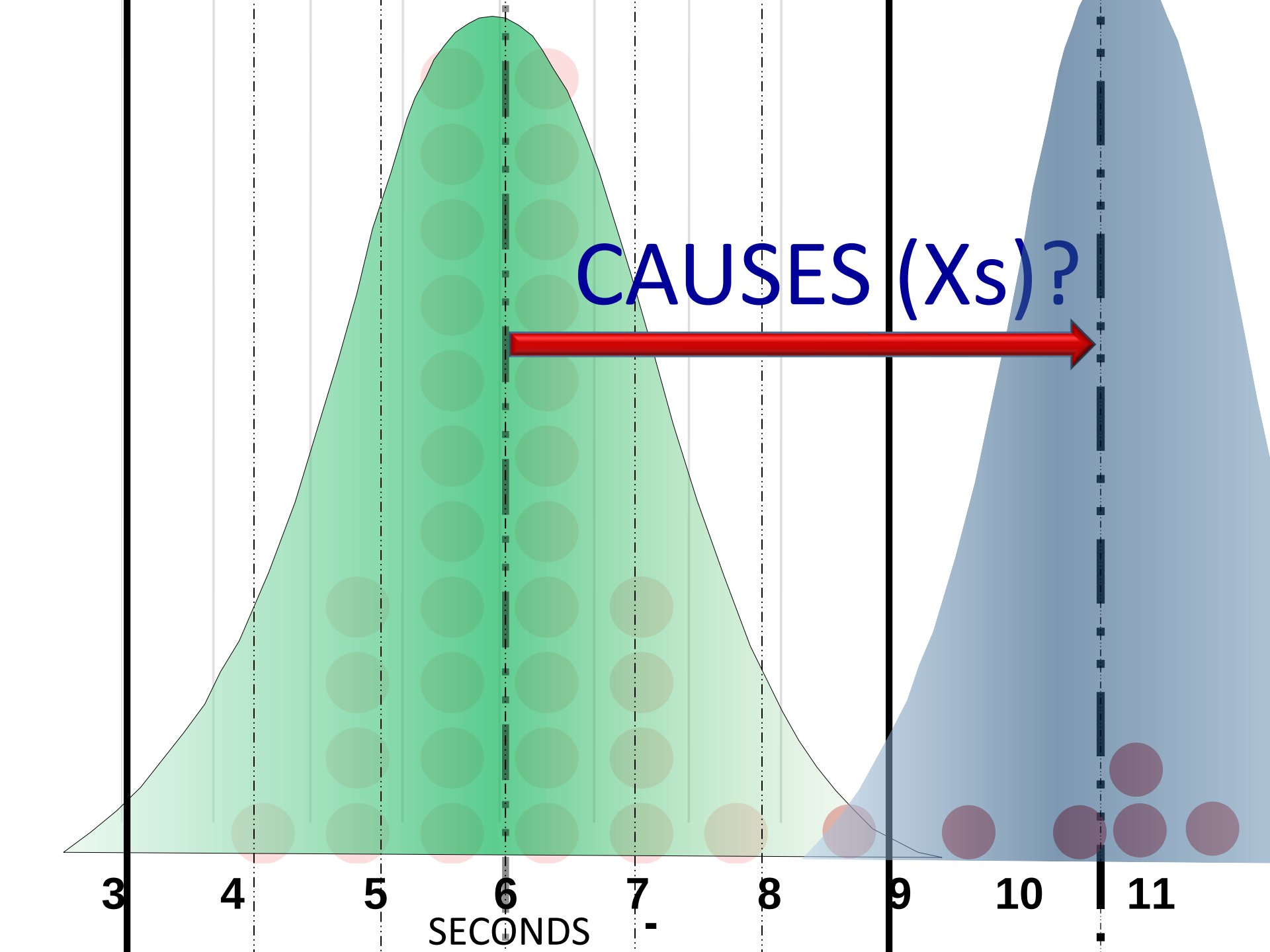

NOISE
IMPROBABLE
EVENT
3
4
5
6
7
8
9
10
11
SECONDS


NOISE
IMPROBABLE
EVENT
3
4
5
6
7
8
9
10
11
SECONDS


NOISE
IMPROBABLE
EVENT
3
4
5
6
7
8
9
10
11
SECONDS


NOISE
IMPROBABLE
EVENT
3
4
5
6
7
8
9
10
11
SECONDS


NOISE
SIGNALS
3
4
5
6
7
8
9
10
11
SECONDS


CAUSES (Xs)?
3
4
5
6
7
8
9
10
11
SECONDS

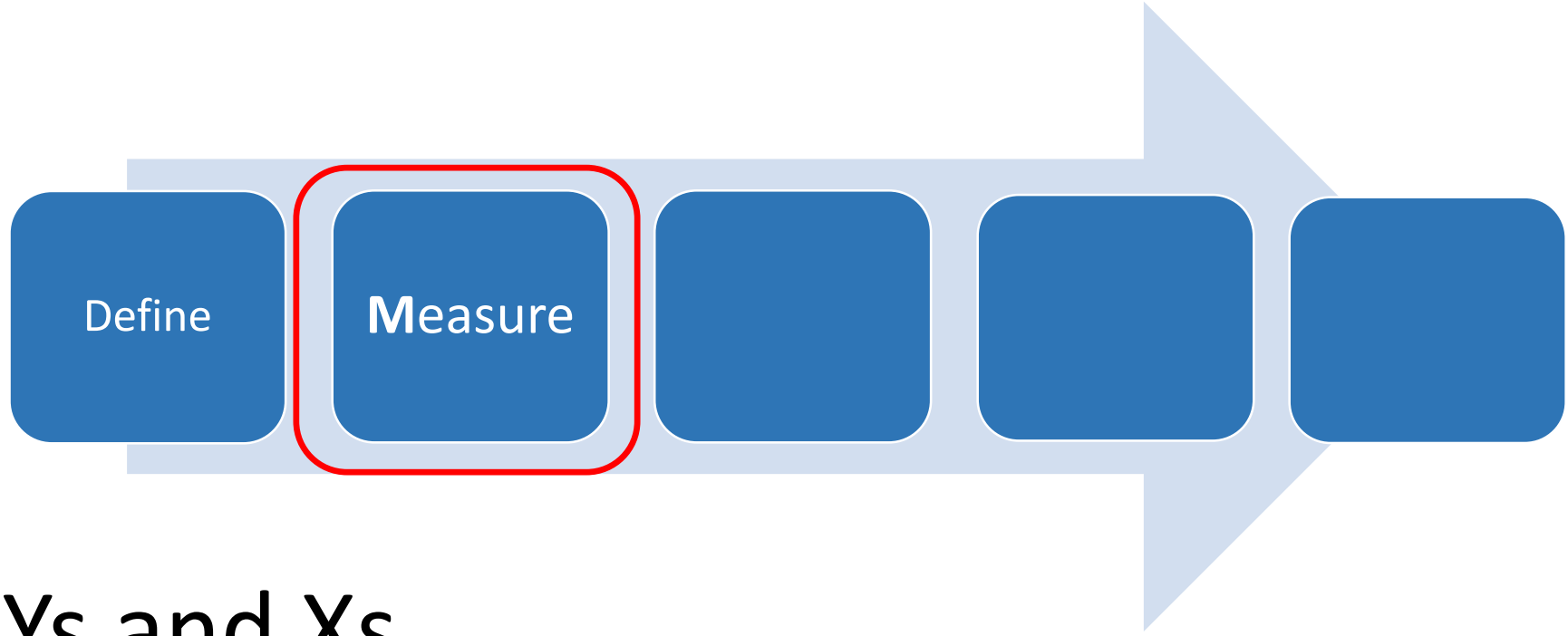
DMAIC

SIX SIGMA
Theme 3

SYSTEMATIC PROCESS IMPROVEMENT

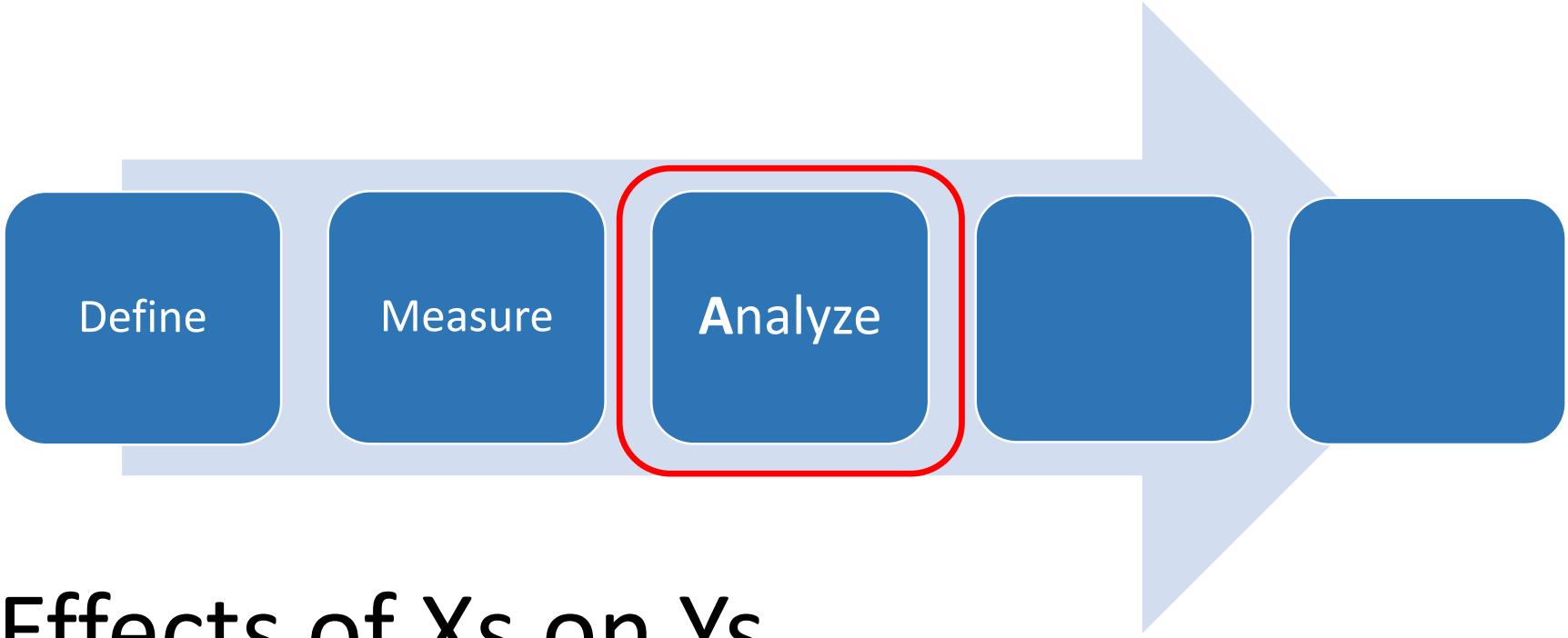
Ys and Candidate Xs

SYSTEMATIC PROCESS IMPROVEMENT



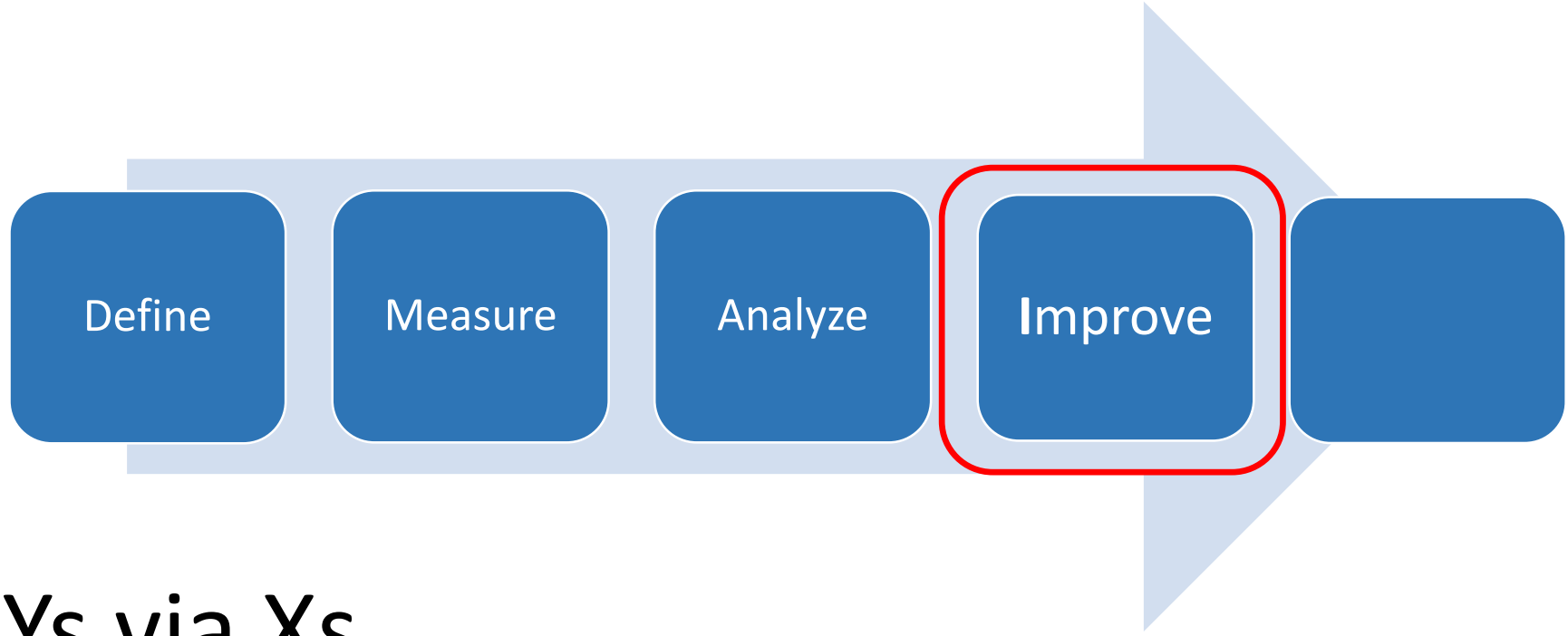
Ys and Xs

SYSTEMATIC PROCESS IMPROVEMENT



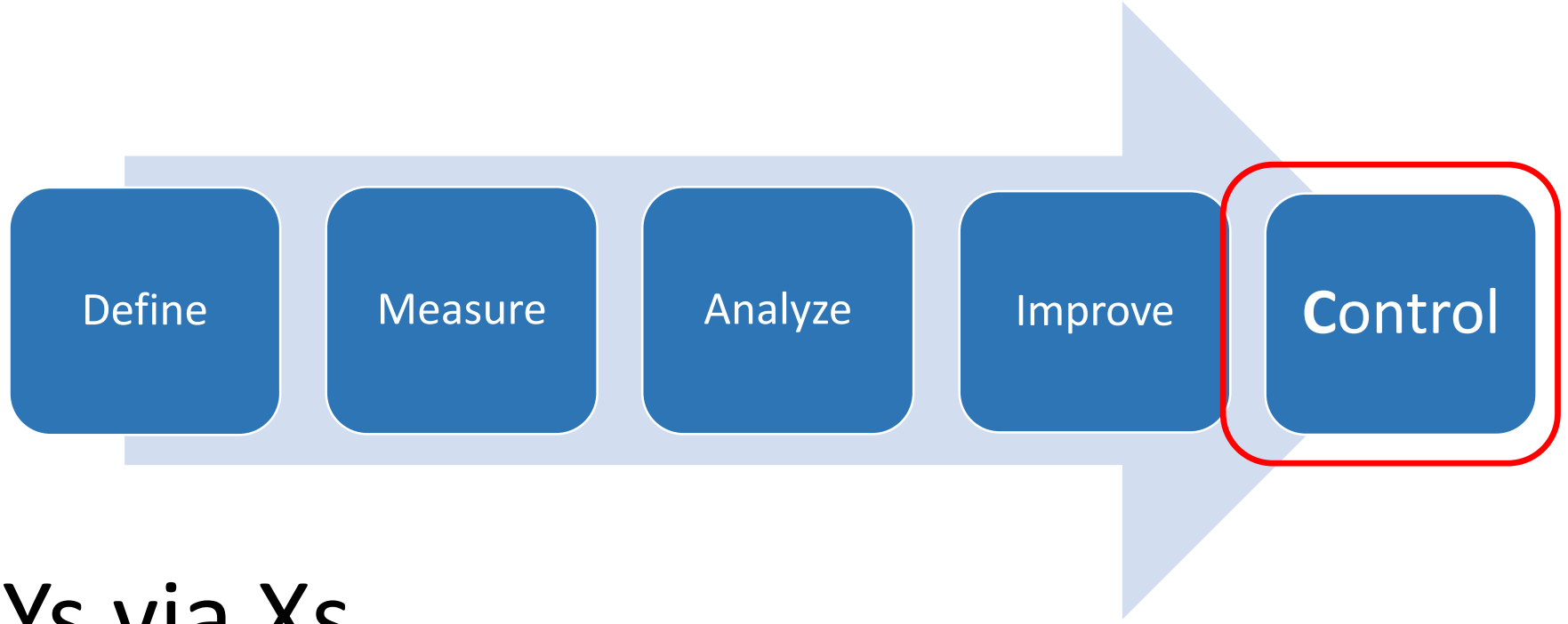
Effects of Xs on Ys

SYSTEMATIC PROCESS IMPROVEMENT



Ys via Xs

SYSTEMATIC PROCESS IMPROVEMENT



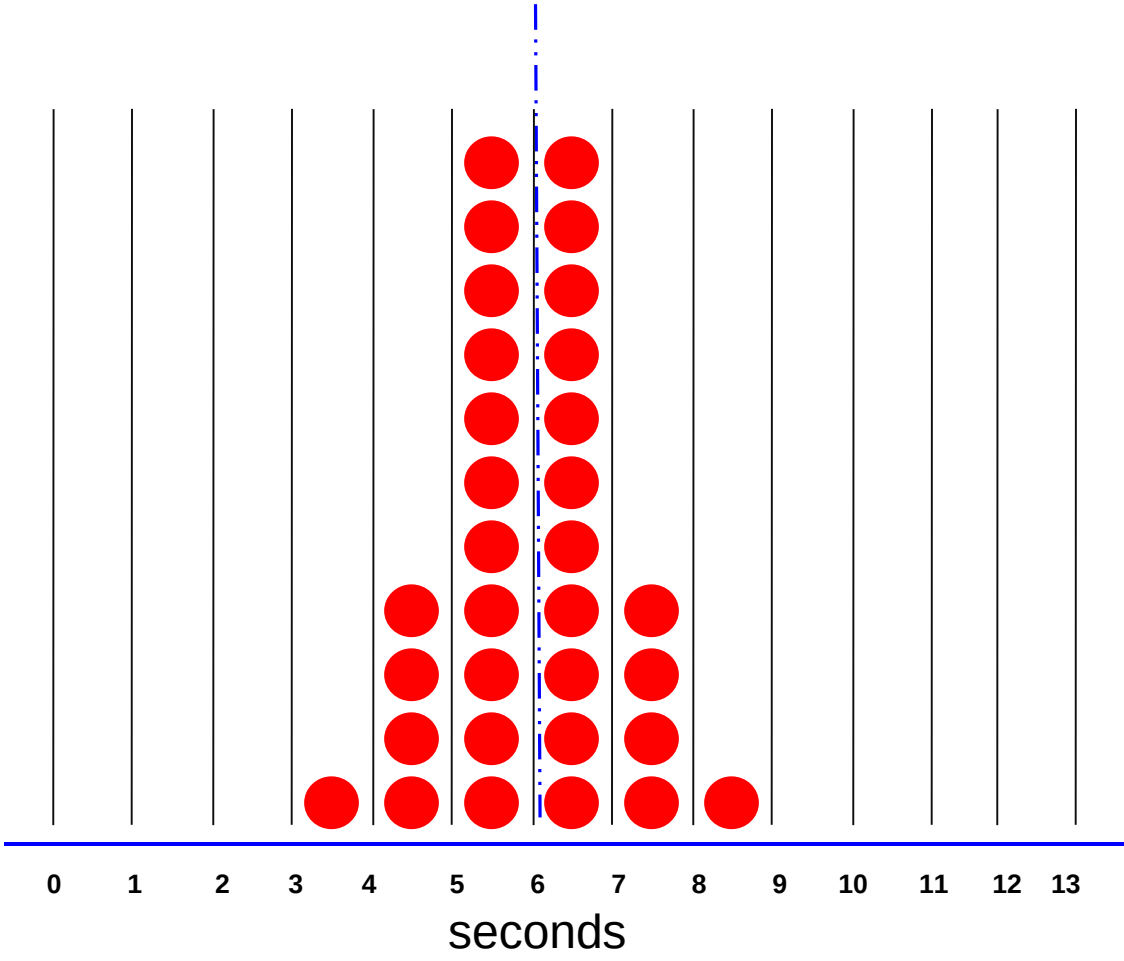
Ys via Xs

SIX SIGMA -- METHODS

VARIATION

SECS TO ANSWER A CALL

HISTOGRAM



VARIATION

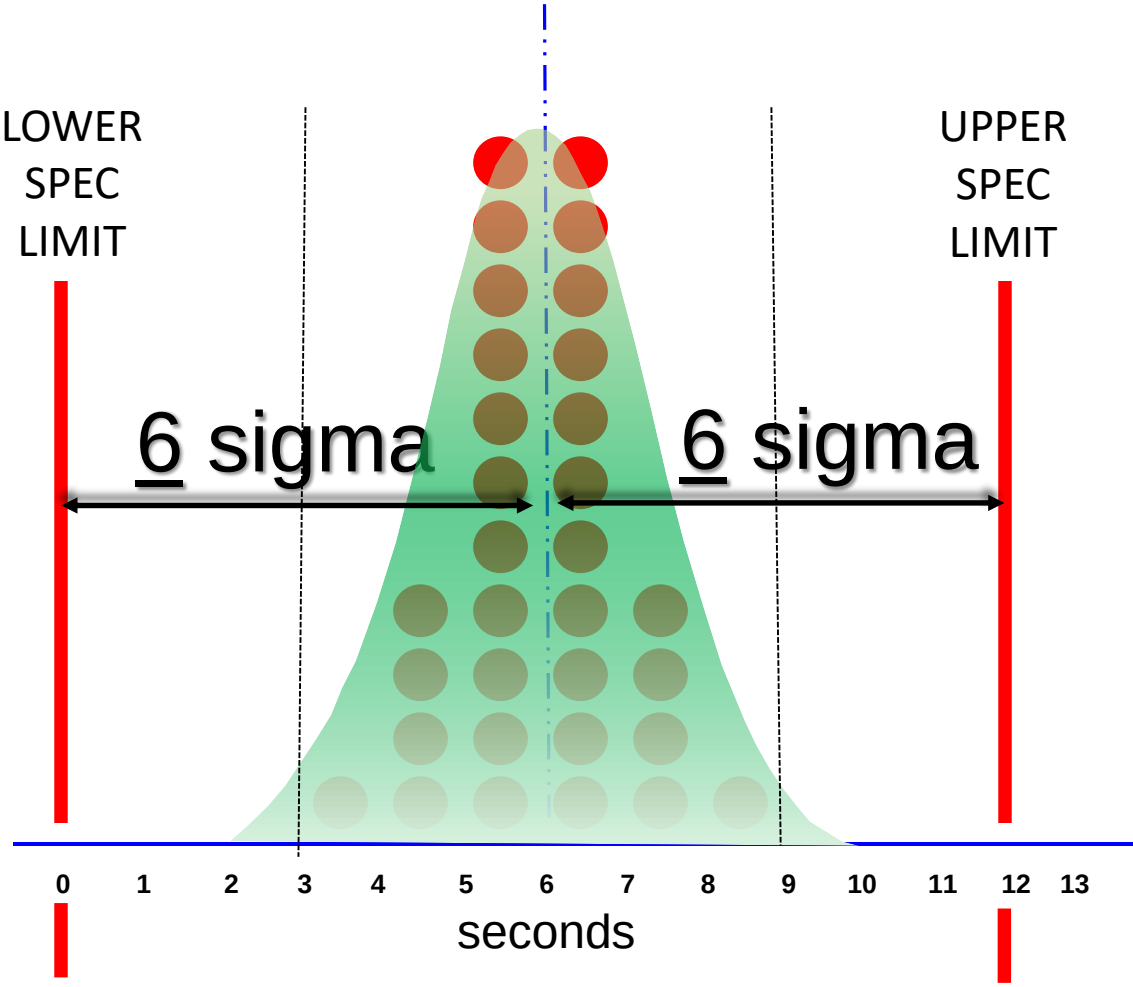
SECS TO ANSWER

CALL VS.

TOLERANCE LIMITS

CAPABILITY

(_SIGMA LEVEL PROCESS)



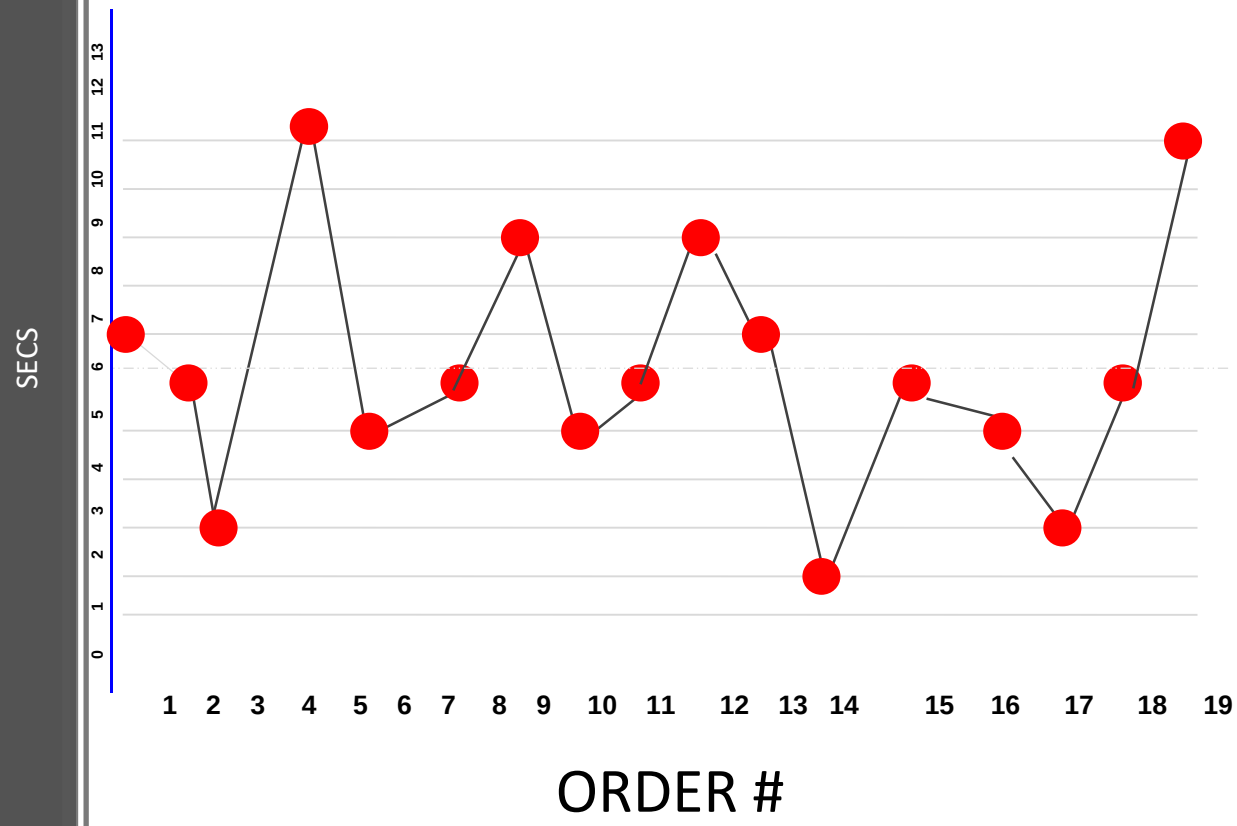
VARIATION

SECS TO ANSWER

CALL VS. ORDER

(TIME)

RUN CHART



VARIATION

SECS TO ANSWER

CALL VS. ORDER

(TIME)

TOLERANCE CHART

UPPER SPEC LIMIT

LOWER SPEC LIMIT

VARIATION

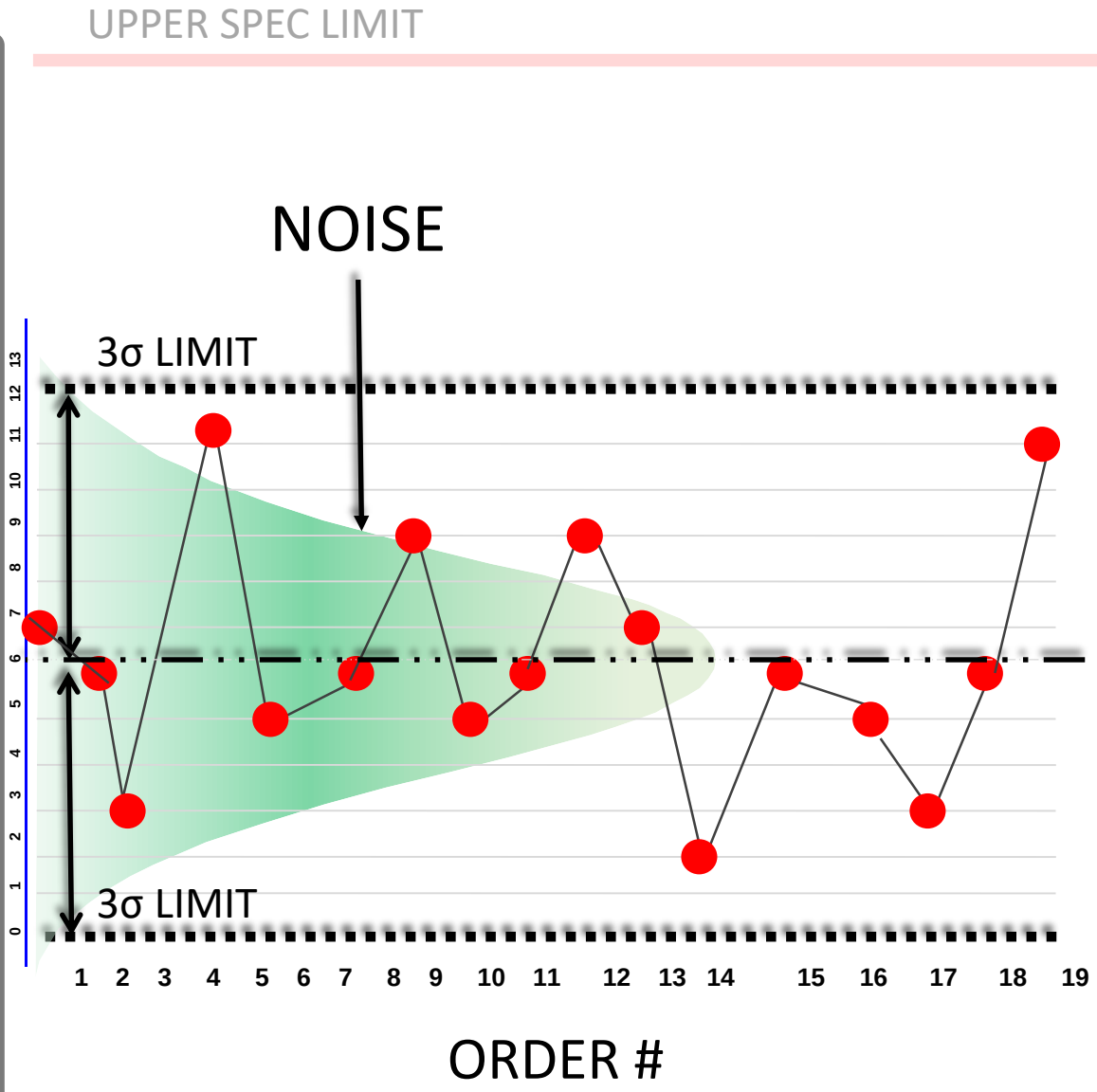
SECS TO ANSWER

CALL

VS. ORDER VS.

3-SIGMA LIMITS

CONTROL CHART



VARIATION

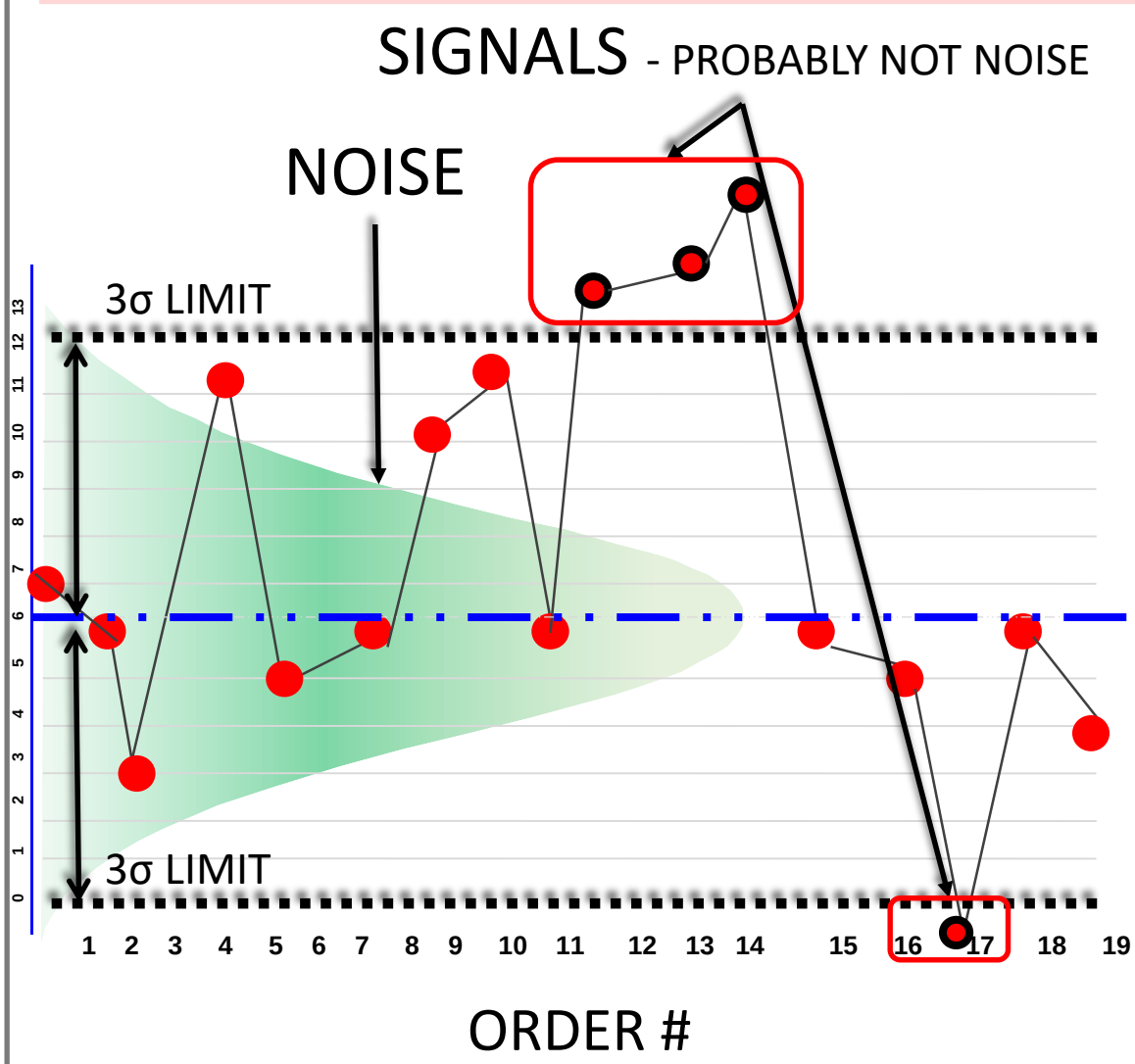
SECS TO ANSWER

CALL

VS. ORDER VS.

3-SIGMA LIMITS

CONTROL CHART



VARIATION

SECS TO ANSWER

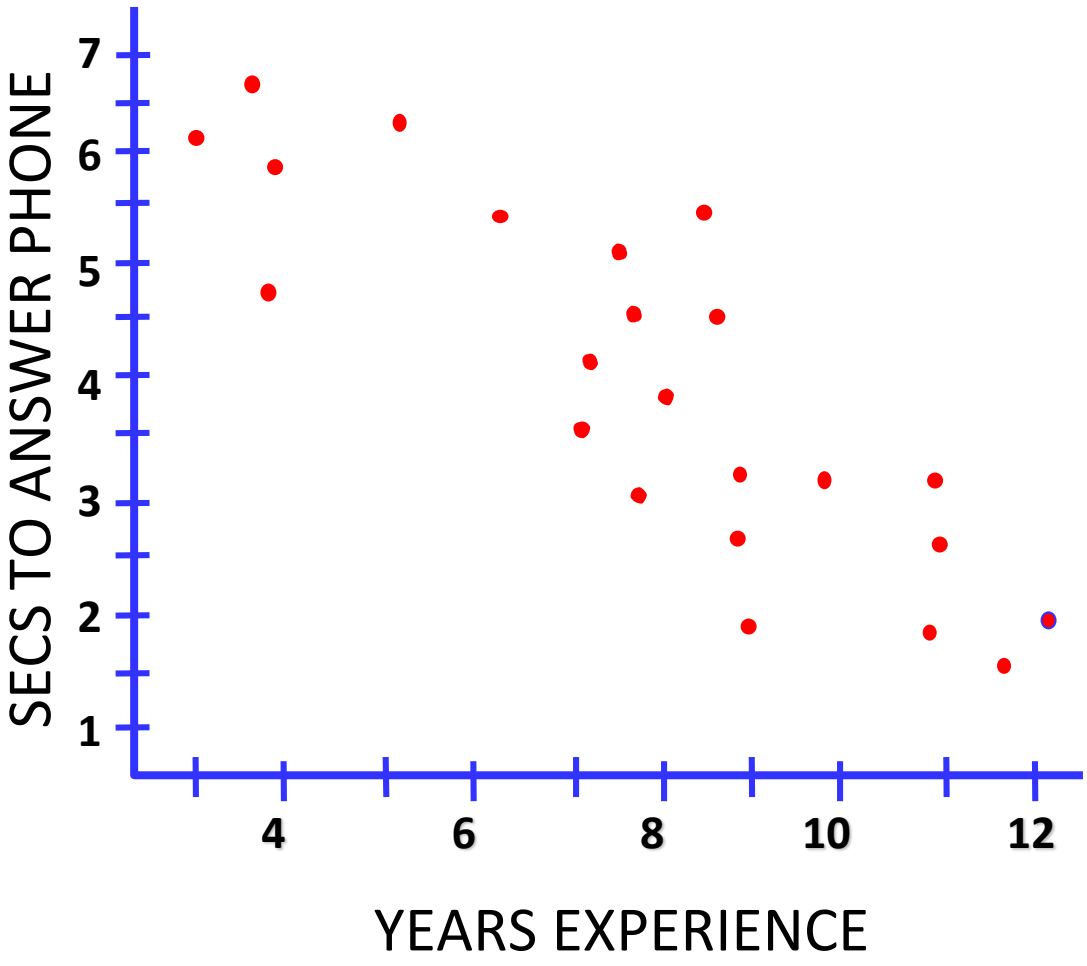
CALL

VS. YEARS

EXPERIENCE

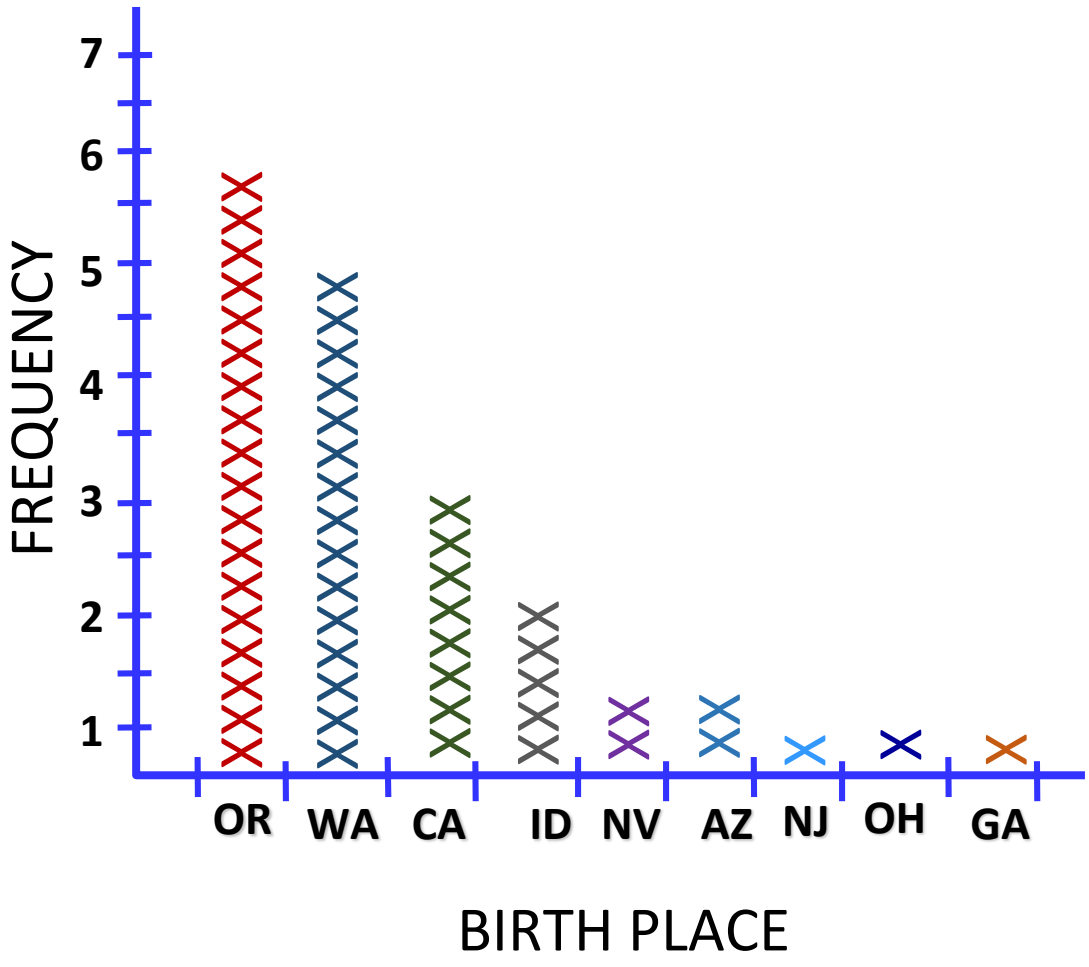
SCATTER

PLOT



VARIATION IN BIRTHPLACE

PARETO CHART



COMPETE OR COMPLEMENT? –

LSS PROJECT EXAMPLE

EMERGENCY ROOM PATIENT WAIT TIME

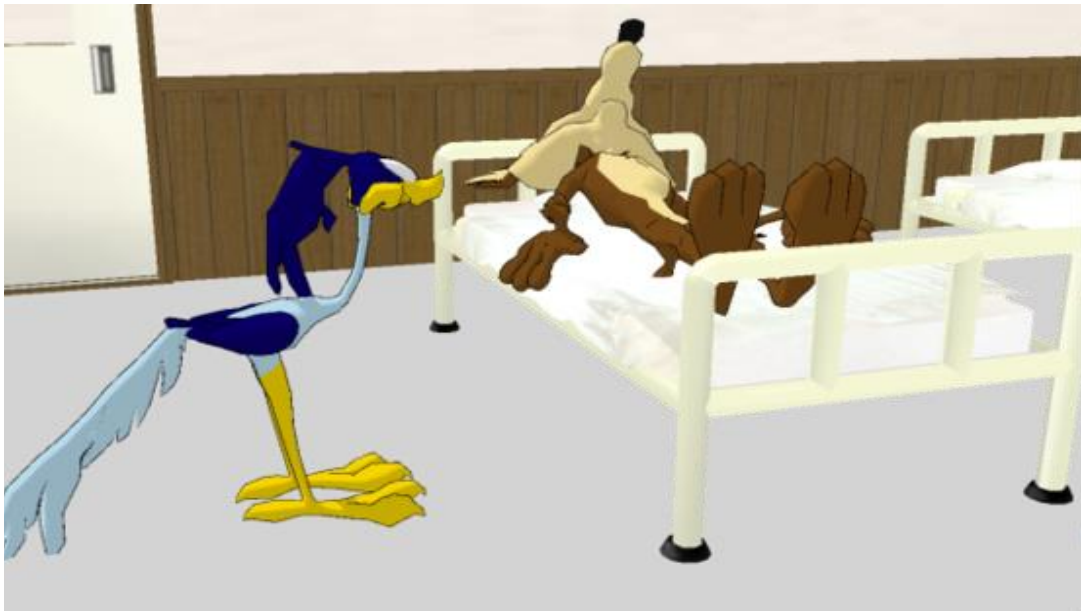
ACMEVILLE

ACMEITES

YOU MAY KNOW

ACMEITES

YOU MAY KNOW



EMERGENCY ROOM PATIENT PROCESSING

$Y_{critical}$

WAIT TIME

DEFINE

IDEALLY

- PATIENTS ENTER AND RECEIVE

  IMMEDIATE & **EFFECTIVE**

  ATTENTION

CURRENTLY

$Y_{critical}$	CURRENTLY
Wait Time Avg.	**24 min**
Wait Times > 45 min	**10%**
Process Capability	**1.2σ**

PROJECT GOALS

$Y_{critical}$	Currently	Goal
Wait Time Avg.	24	**≤ 12 min**
Wait Times > 45 min	10%	**≤ 1%**
Process Capability	1.2σ	**≥ 4.0σ**

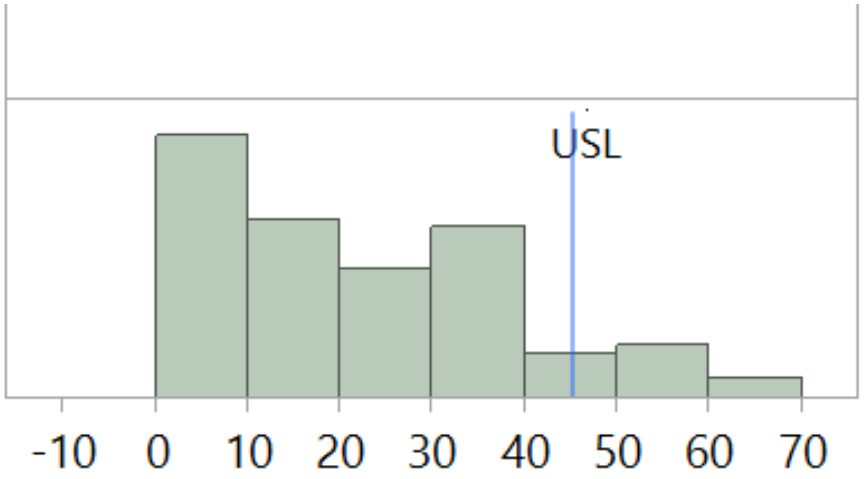
EMERGENCY ROOM PATIENT PROCESSING

$Y_{critical}$

WAIT TIME

MEASURE/ANALYZE

FINDINGS BEFORE – WAIT TIME

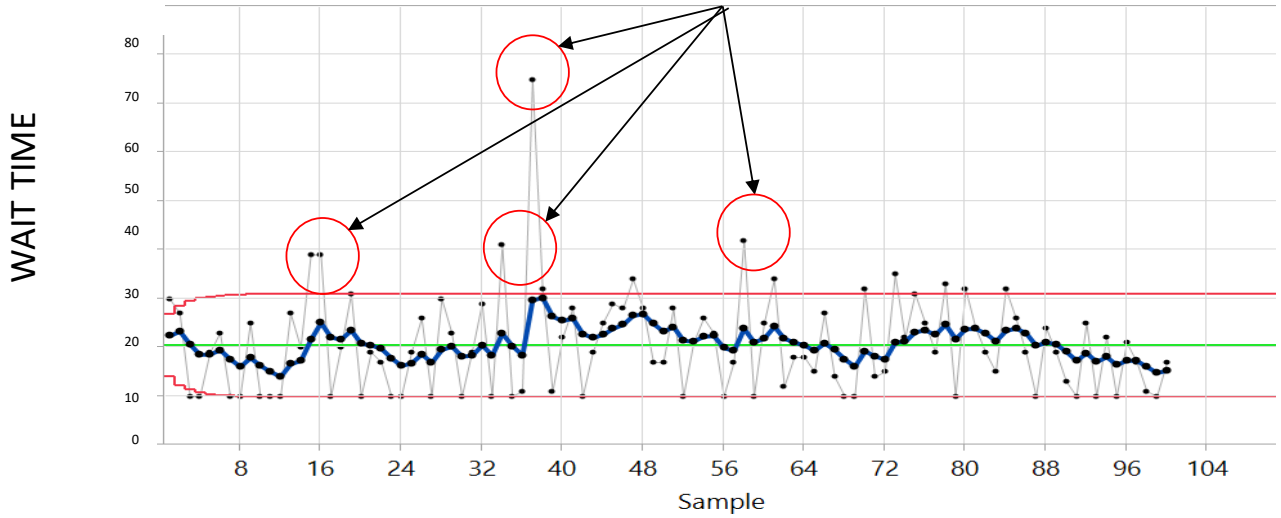


HISTOGRAM

- Average = 24 min
- 10%>45 min

FINDINGS BEFORE – WAIT TIME

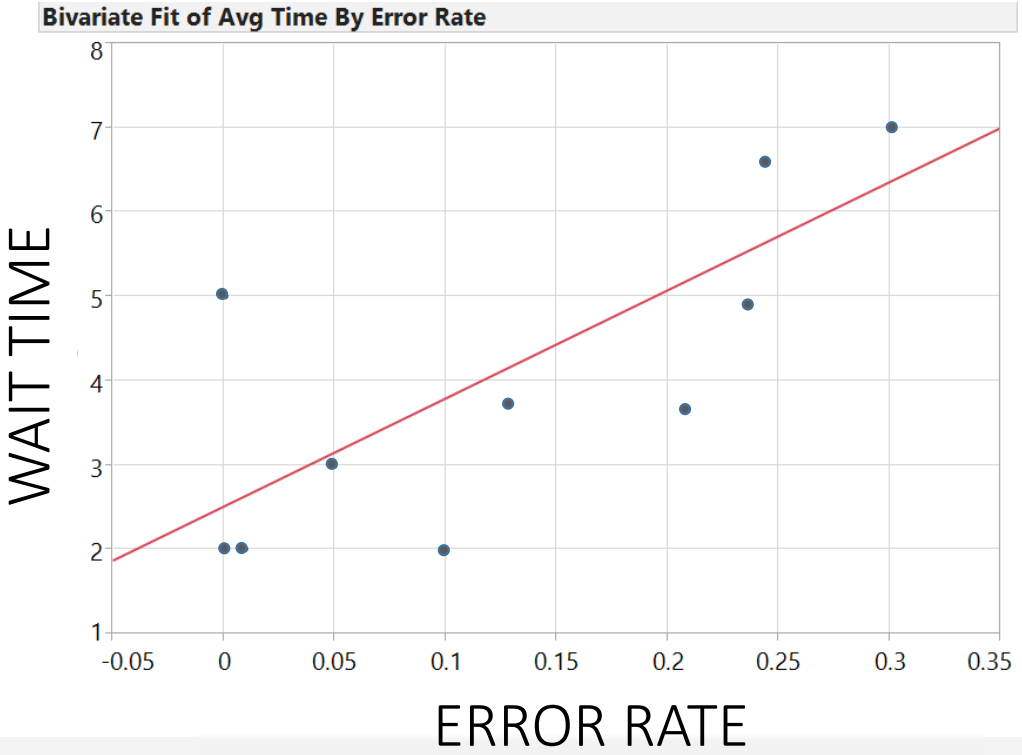
STATISTICAL CONTROL CHART W/3σ LIMITS



- No indications of cycles, trends, other systematic effects
- Occasional exceptionally long waiting times

FINDINGS BEFORE – WAIT TIME VS. ERRORS

SCATTER PLOT



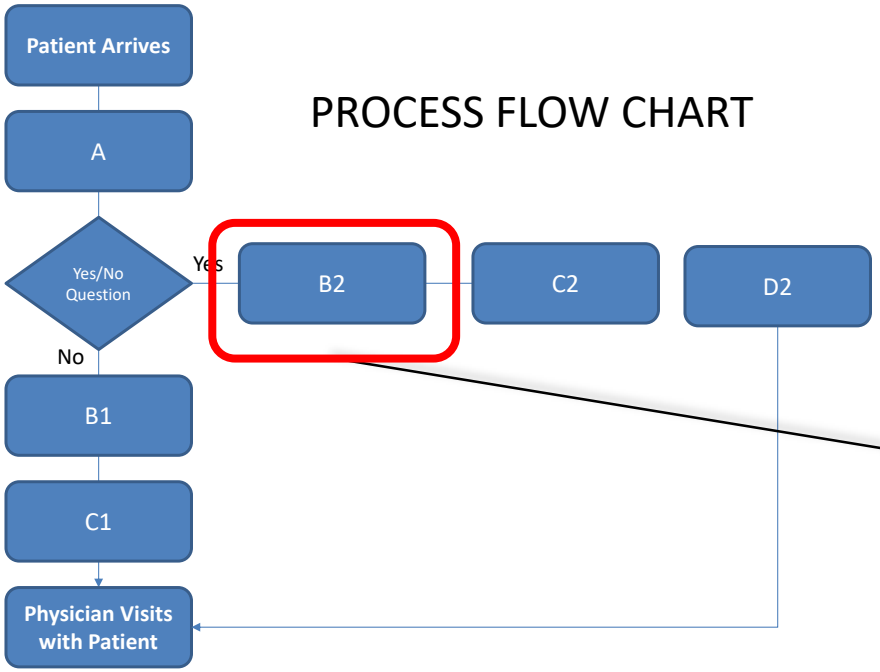
Error Rate

CORRELATED with

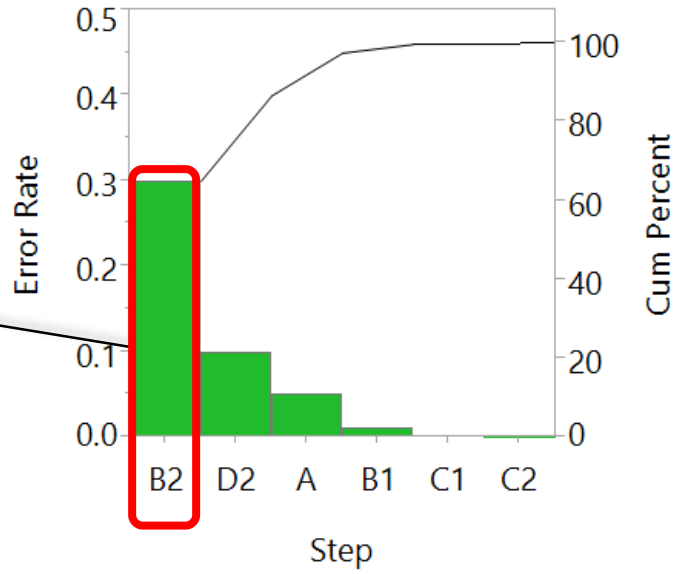
Wait Time.

FINDINGS BEFORE – ERRORS

PROCESS FLOW CHART



PARETO CHART
Error Rate by Step (Before)



Opportunity - Reduce step B2 error rate.

OTHER FINDINGS

- 90% of B2 errors = data omission (defects/errors)
- Multiple redundant activities during paperwork prep (over-processing)

PAPERWORK

- Room changeover times excessive (large % NVA – excess motion)

ROOM

EMERGENCY ROOM PATIENT PROCESSING

$Y_{critical}$

WAIT TIME

IMPROVE

COUNTERMEASURES

PAPERWORK --

1. POKA-YOKE electronic work order form.

2. Eliminate NON-VALUE ADDING redundant steps for paperwork.

COUNTERMEASURES

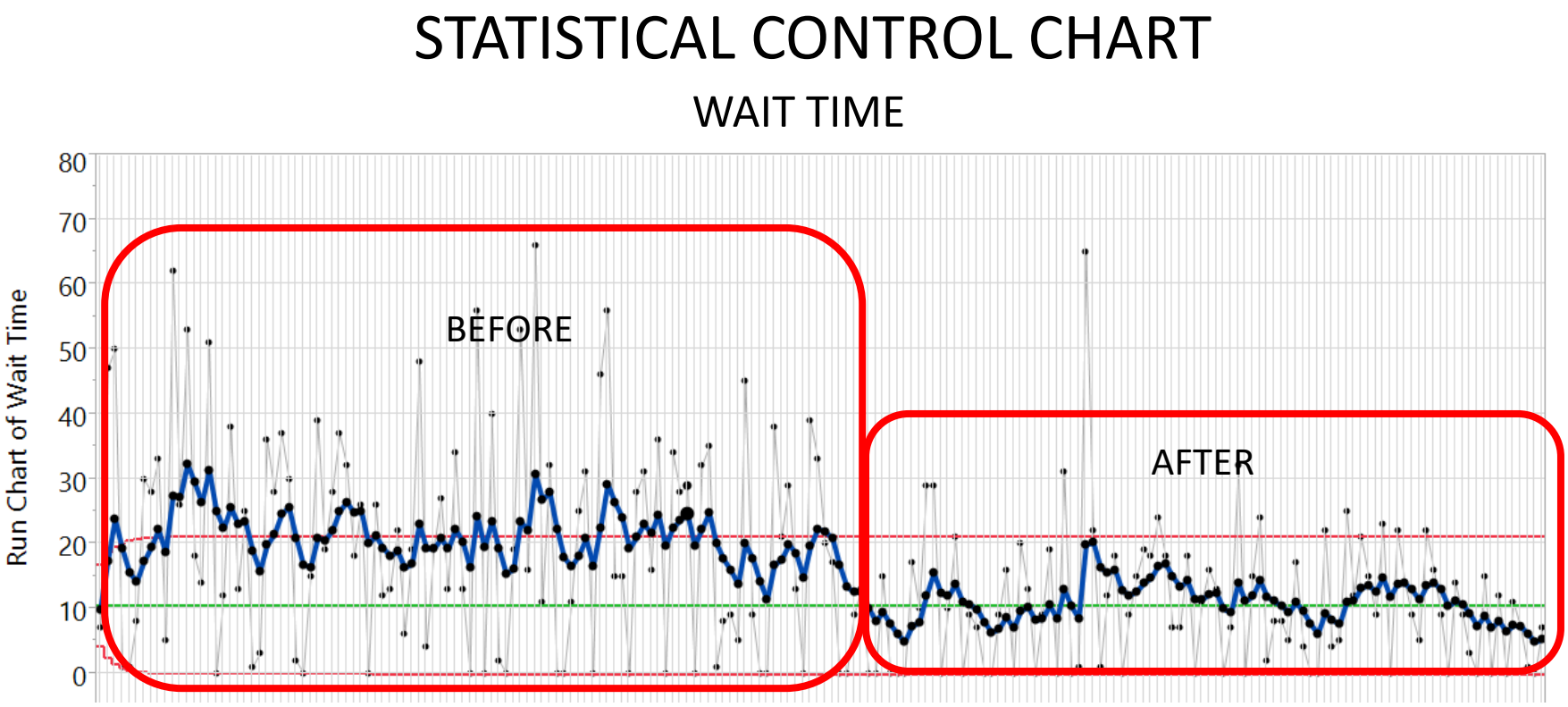
ROOM --

1. 5S room layout.

2. SMED for room prep between patients.

3. STANDARD WORK to assure consistency.

VALIDATION


STATISTICAL CONTROL CHART
WAIT TIME
Run Chart of Wait Time
80
70
60
50
40
30
20
10
0
BEFORE
AFTER

IMPROVEMENT

$Y_{critical}$	Before	Goal	After
Wait Time Avg.	24	≤ 12 min	**10.5 min**
Wait Times > 45 min	10%	≤ 1%	**< 1%**
Process Capability	1.2σ	≥ 4.0σ	**4.0σ**

EMERGENCY ROOM PATIENT PROCESSING

$Y_{critical}$

WAIT TIME

CONTROL

CONTROL PLAN

1. Poka Yoke controls designed into Step B2.

2. Conduct regular 5S audits.

3. Control chart wait time for each transaction.

4. Meet weekly to review for special cause variation and root causes.

EMERGENCY ROOM PATIENT PROCESSING

$Y_{critical}$

WAIT TIME

BENEFITS

BENEFITS - FINANCIAL

- Five Year Savings = $214,000
- Payback Period = 1 year
- IRR = 110%
- NPV = $150,000

BENEFITS – NON-FINANCIAL

- Greater Customer Loyalty
- Reduced Safety risks
- Heightened Employee Morale

COMPETE OR COMPLEMENT? –

LEAN AND SIX SIGMA ROLES

METHODS

ROLES

SIX SIGMA

- Histogram
- Capability
- Control Chart
- Scatter Plot
- Pareto Analysis

- DISCOVER
- VALIDATE
- CONTROL

METHODS

ROLES

LEAN

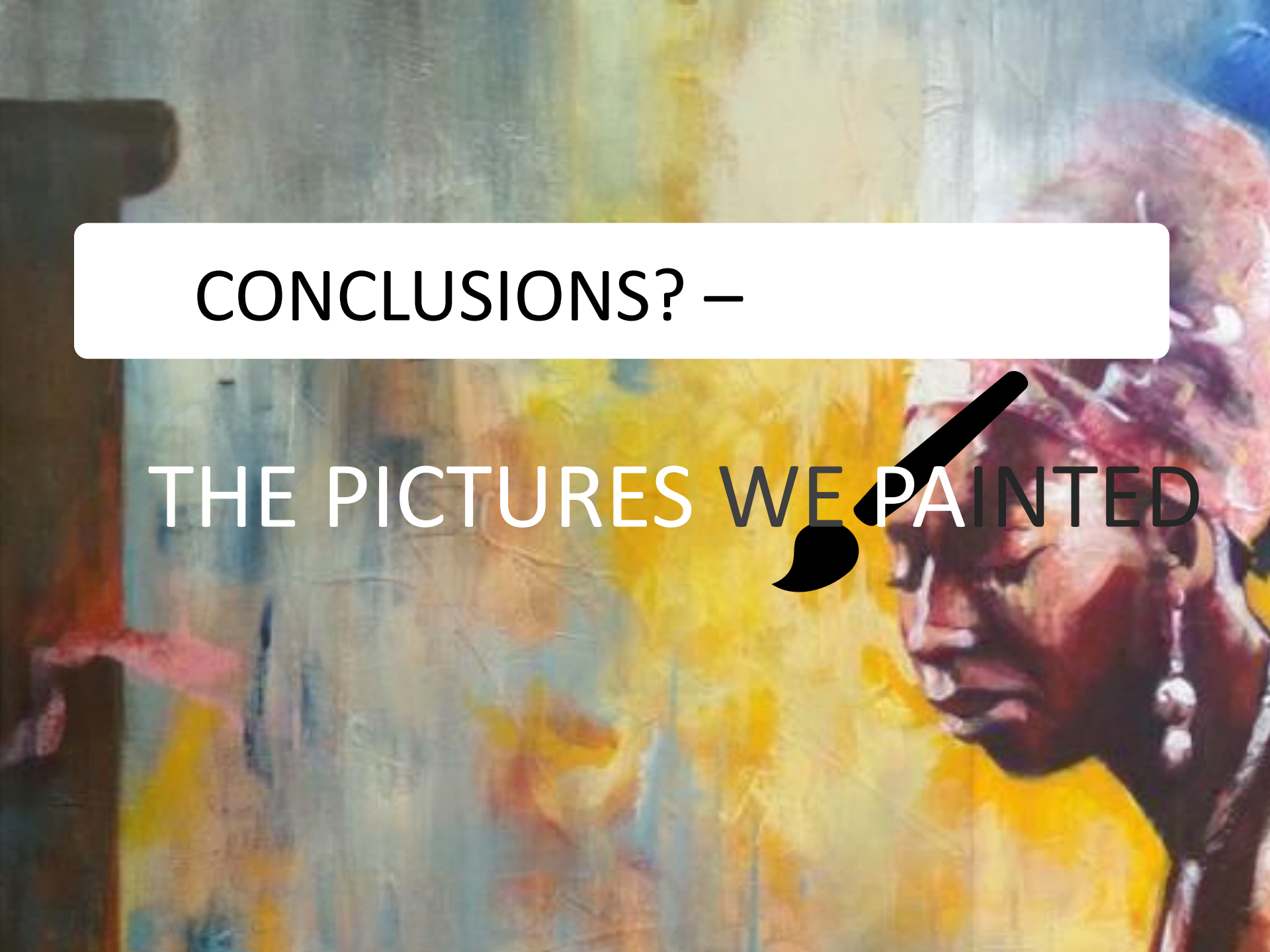
- Flow Chart
- Value Stream Analysis
- Poka Yoke
- 5S
- SMED
- Standard Work
- Pareto Analysis

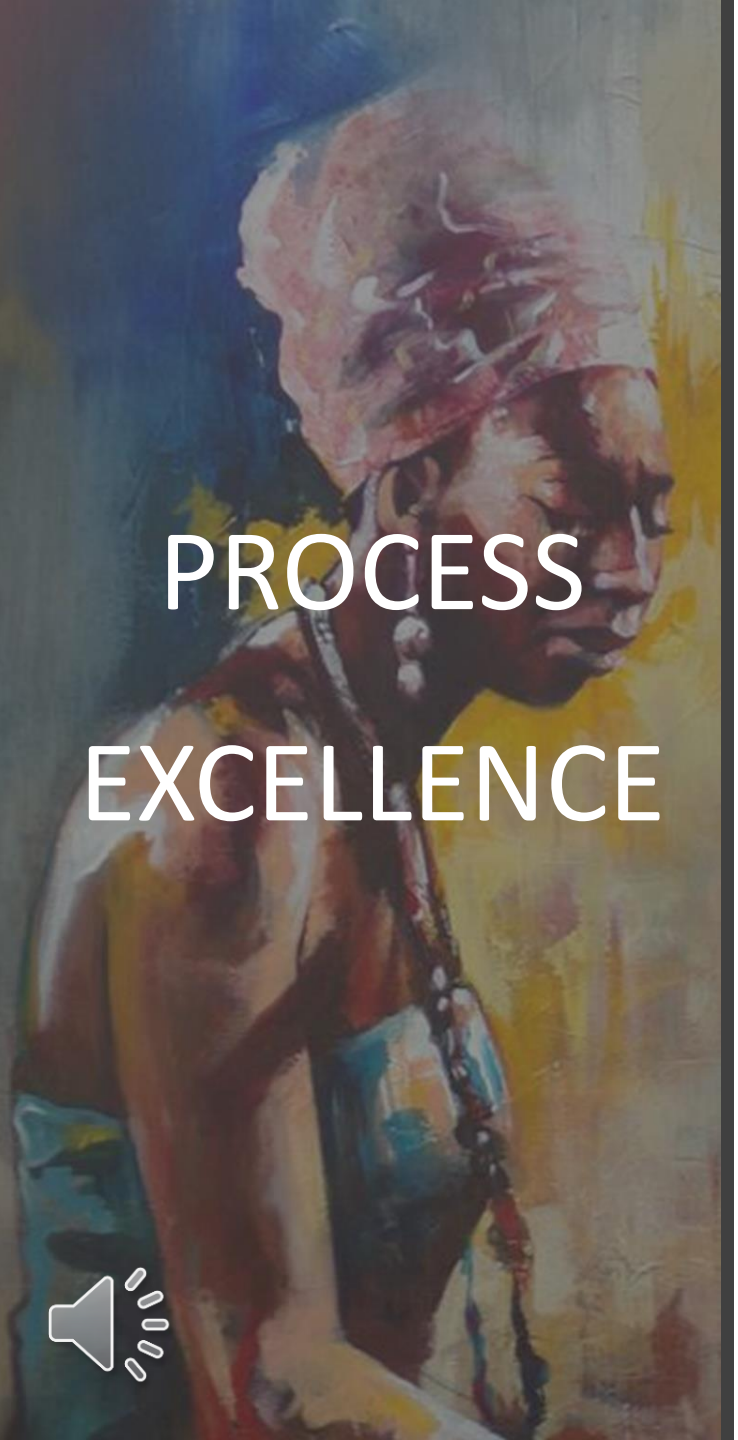
- DISCOVER
- IMPROVE
- CONTROL

METHODS

ROLES

SIX SIGMA	LEAN
• DISCOVER	• DISCOVER
• VALIDATE	• IMPROVE
• CONTROL	• CONTROL


CONCLUSIONS? –
THE PICTURES WE PAINTED


PROCESS
EXCELLENCE

INSIGHTFUL
CUSTOMER
PRODUCTIVE
VISION
TIMELY
TARGETED
CONSISTENT

CONTINUALLY REDUCE VARIATION

CONTINUALLY DISCOVER

CONTINUALLY ELIMINATE WASTE

CONTINUALLY TARGET

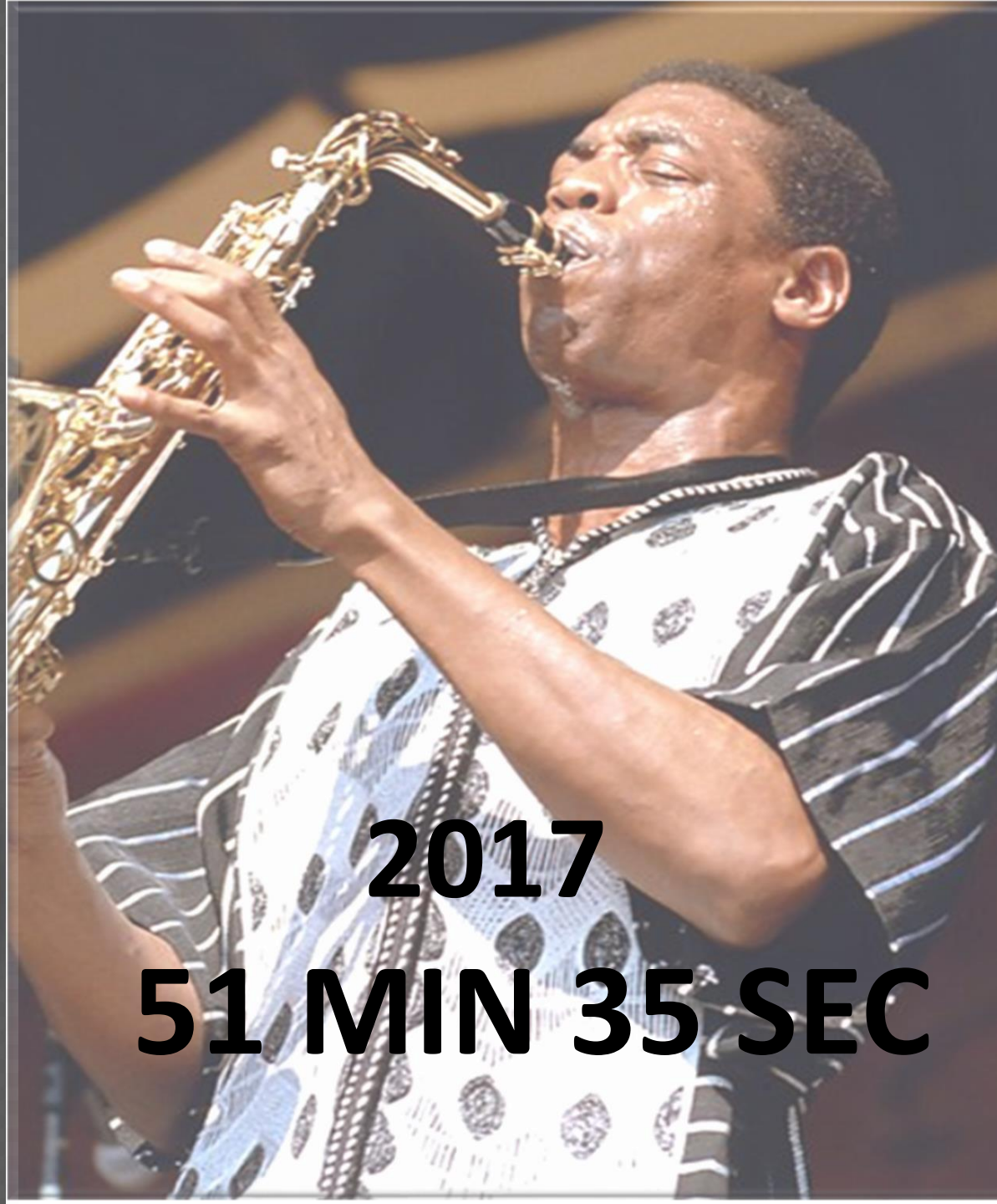
PROJECT MANAGEMENT

LEAN

SIX SIGMA

EXCELLENCE
1997
45 min 47 sec

CONTINUAL IMPROVEMENT



2017

51 MIN 35 SEC

EXCELLENCE

1935

714 HOME RUNS

CONTINUAL IMPROVEMENT

1974

715 HOME RUNS

EXCELLENCE

2013 - PDX

950 PEOPLE

CONTINUAL IMPROVEMENT

Hand-in your post-it notes for the drawing

CONTINUALLY ASPIRE!

https://www.youtube.com/watch?v=fZ96efstvak