Presentation to

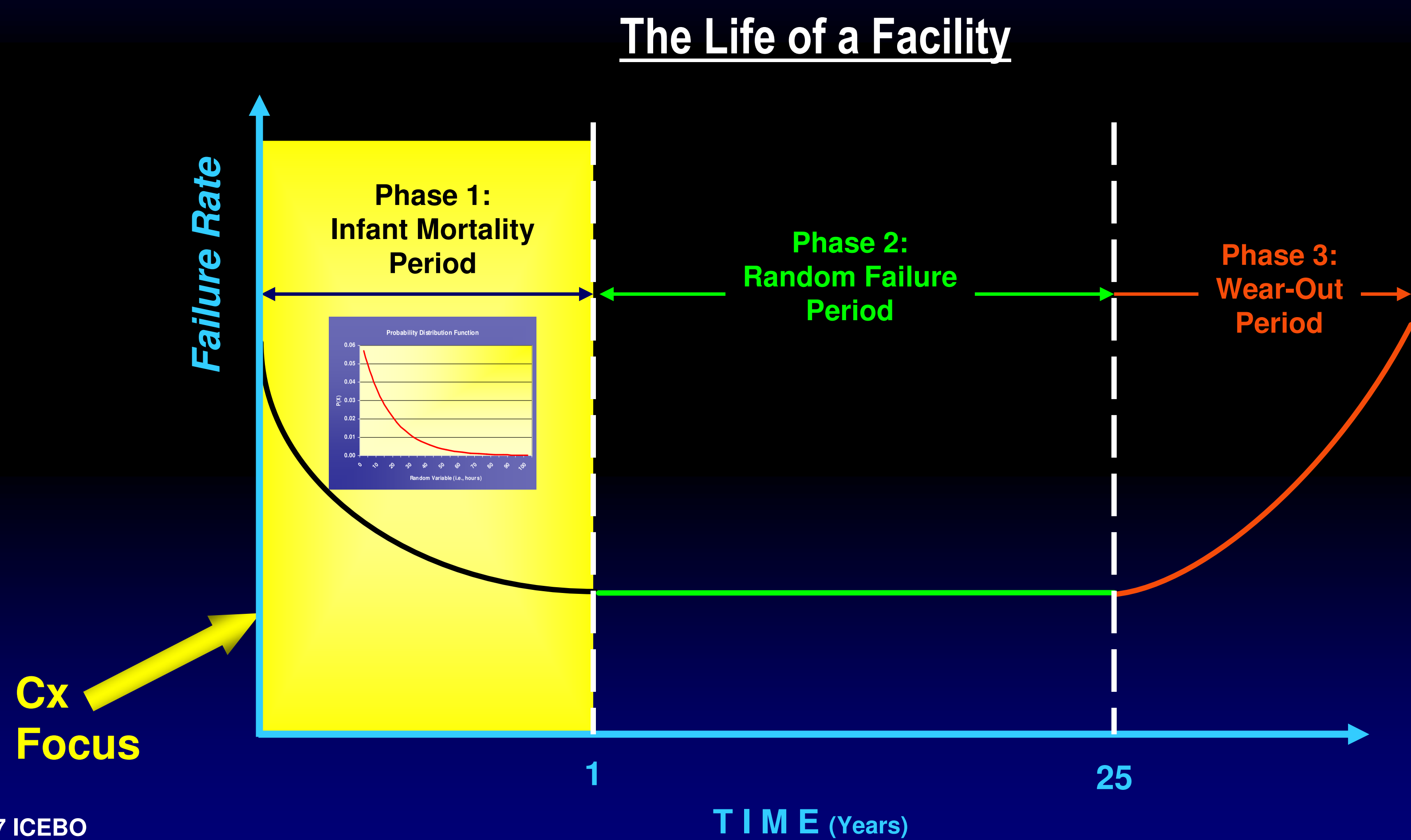
International Conference for Enhanced Building Operations

Enhancing The Commissioning Process On Multi-Building Projects

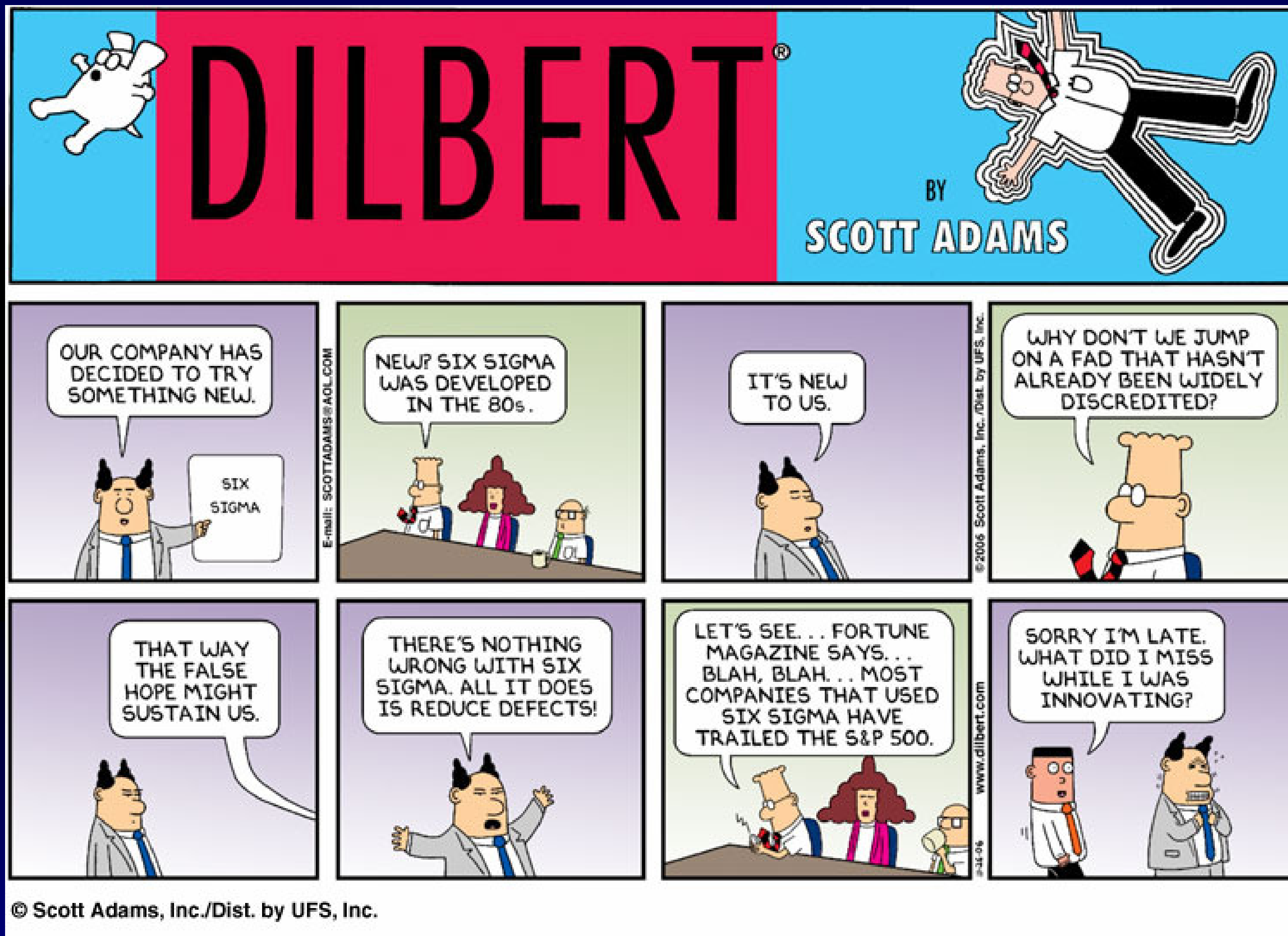
With Six Sigma Tools/Techniques

2007 ICEBO
San Francisco, CA

Commissioning: A Context

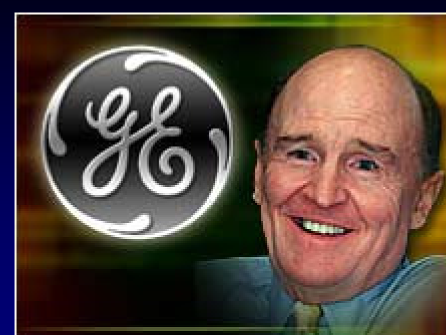


Six Sigma - A Context



"I don't give a damn if we get a little bureaucracy as long as we get the results. If it bothers you, yell at it. Kick it. Scream at it. Break it!"

Jack Welch, 1998



6σ  C_x

Process Fit:

6σ

- Disciplined Methodology
- Customer Focused
- Proven
- Comprehensive
- Flexible
- Consistent

C_x

- Customer Driven
- Quality Assurance Program
- Infrastructure Focused

COMMONALITY

- Quality
- ROI
- Focus on the Owner/Customer
- Customer Satisfaction

VALUE

- Increased Customer Satisfaction
- ROI

Build on Shared Interests to Deliver Value

Agenda:

- ❑ **Very Brief Overview of Six Sigma**
- ❑ **Six Sigma Tools Applied to Commissioning**
- ❑ **Case Study**

6σ

An Overview

Getting Grounded in Reality

- **You don’t know what you don’t know**
- **If you don’t benchmark, you’ll never start to know**
- **If you can’t express what you know numerically, you really don’t know much about it**
- **If you don’t know much about it, you can’t control it**
- **If you can’t control it, you are at the mercy of chance**

What is It?

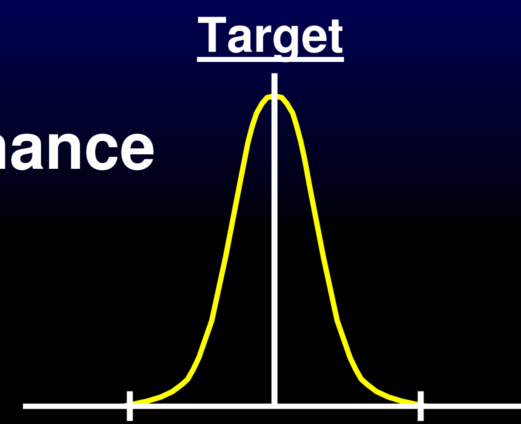
σ

- Letter in the Greek alphabet.
- Used to describe the distribution of any process.
- The “Sigma Value” is a metric. It Indicates how well a process is performing.
- “Six Sigma” is a philosophy aimed at increasing the sigma value of all processes.

Reducing Process Variation

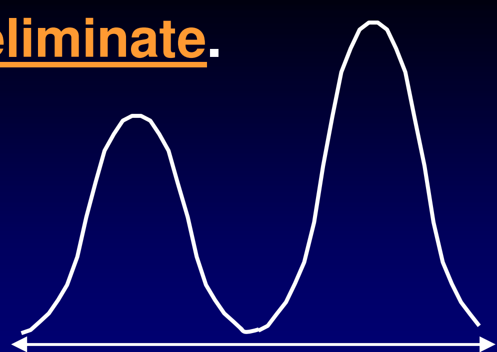
Two Types of Variation

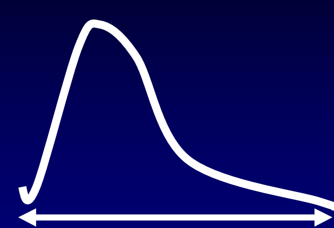
1. **Common Cause – Random/Chance**



2. **Special Cause – Not Random -- Assignable**

   Key factors which contribute to variation and are feasible to detect, identify & eliminate.

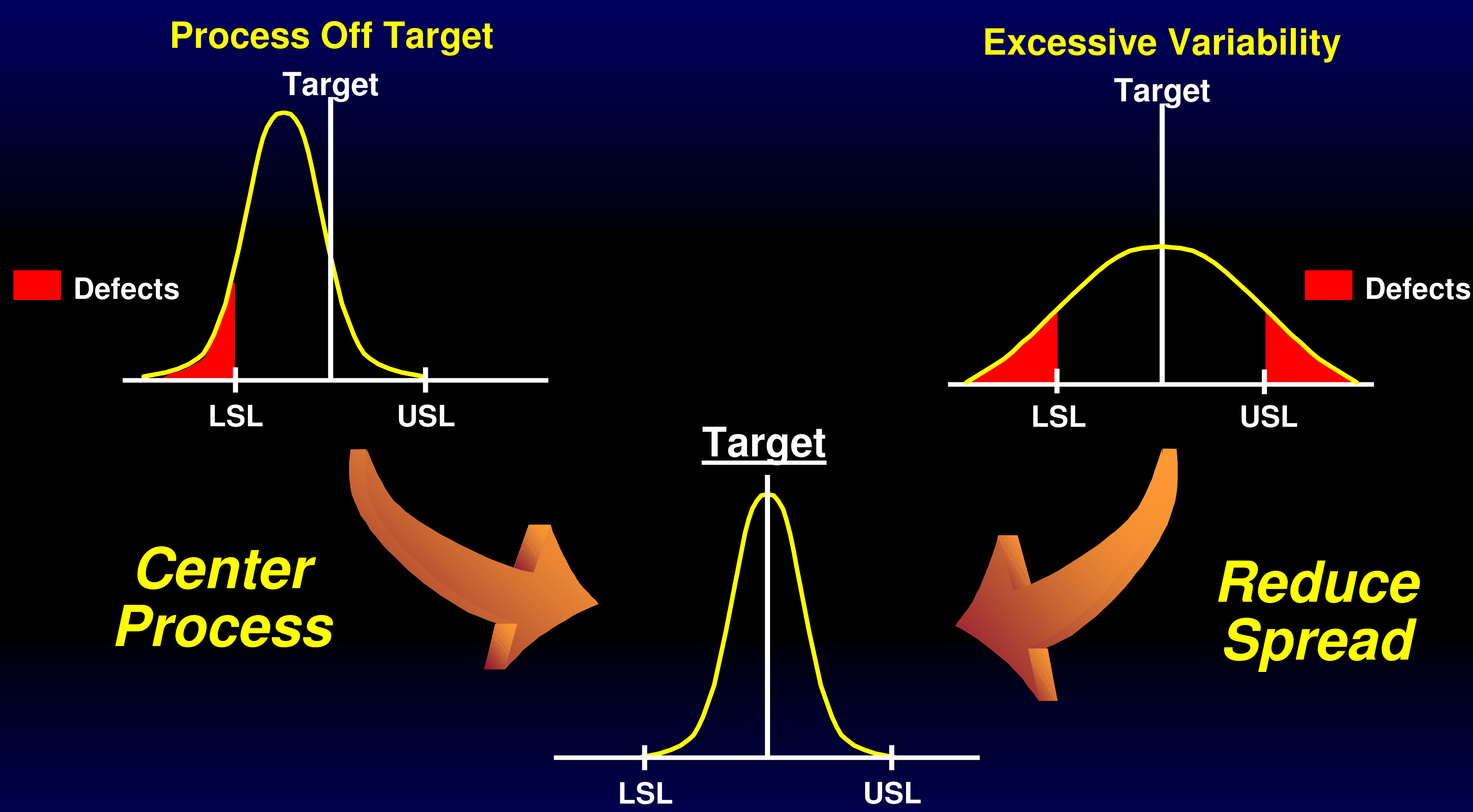




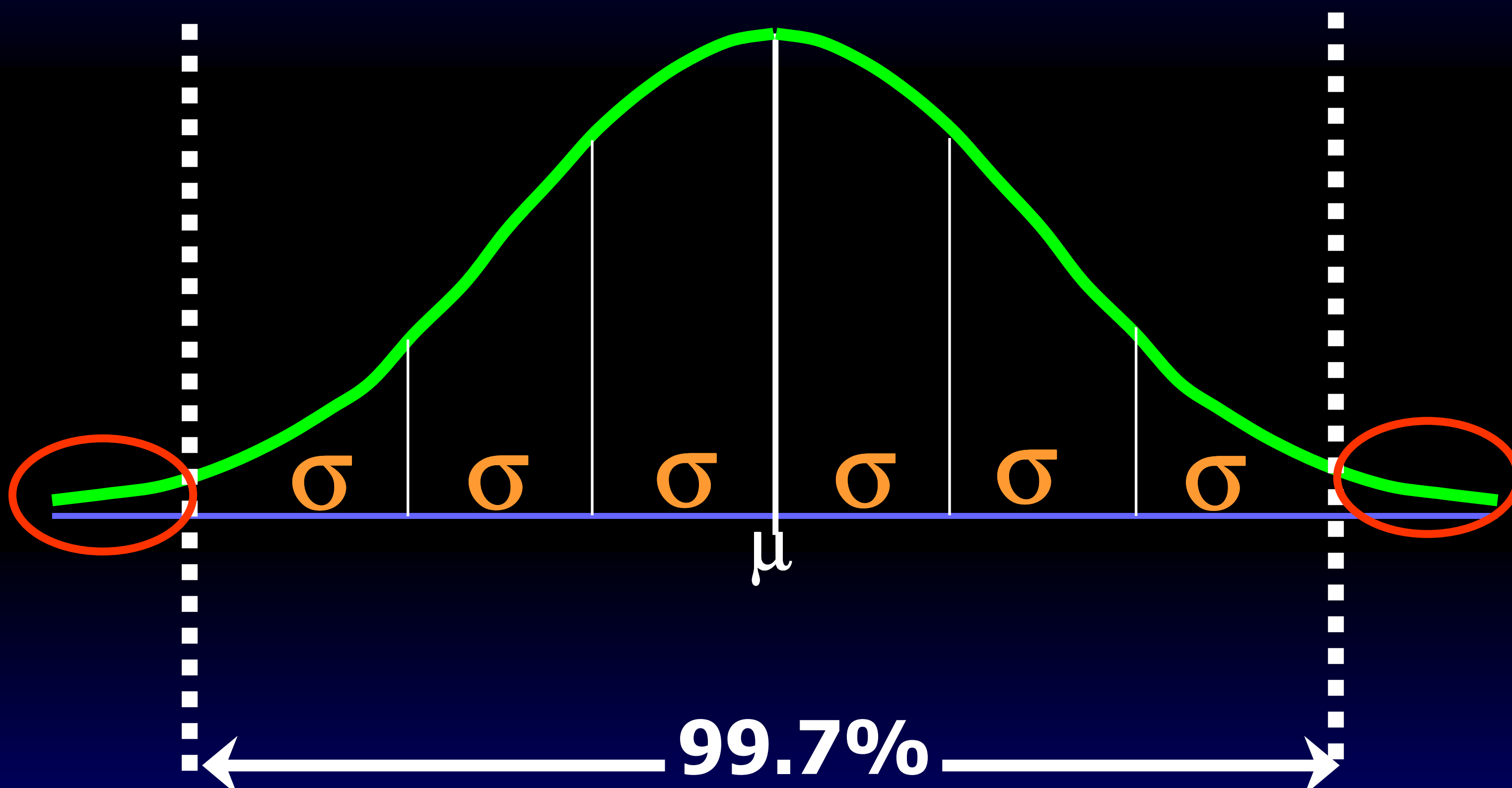
Special Cause Variation - 6 M's

- **Man** – swimmer has the flu
- **Machine** – vault height set incorrectly
- **Material** – defective surface of starting block
- **Method** – broke form on strokes
- **Measurement** – timing clock wrong
- **Mother Nature** – 100 degrees & humid

The Statistical Objective of Six Sigma



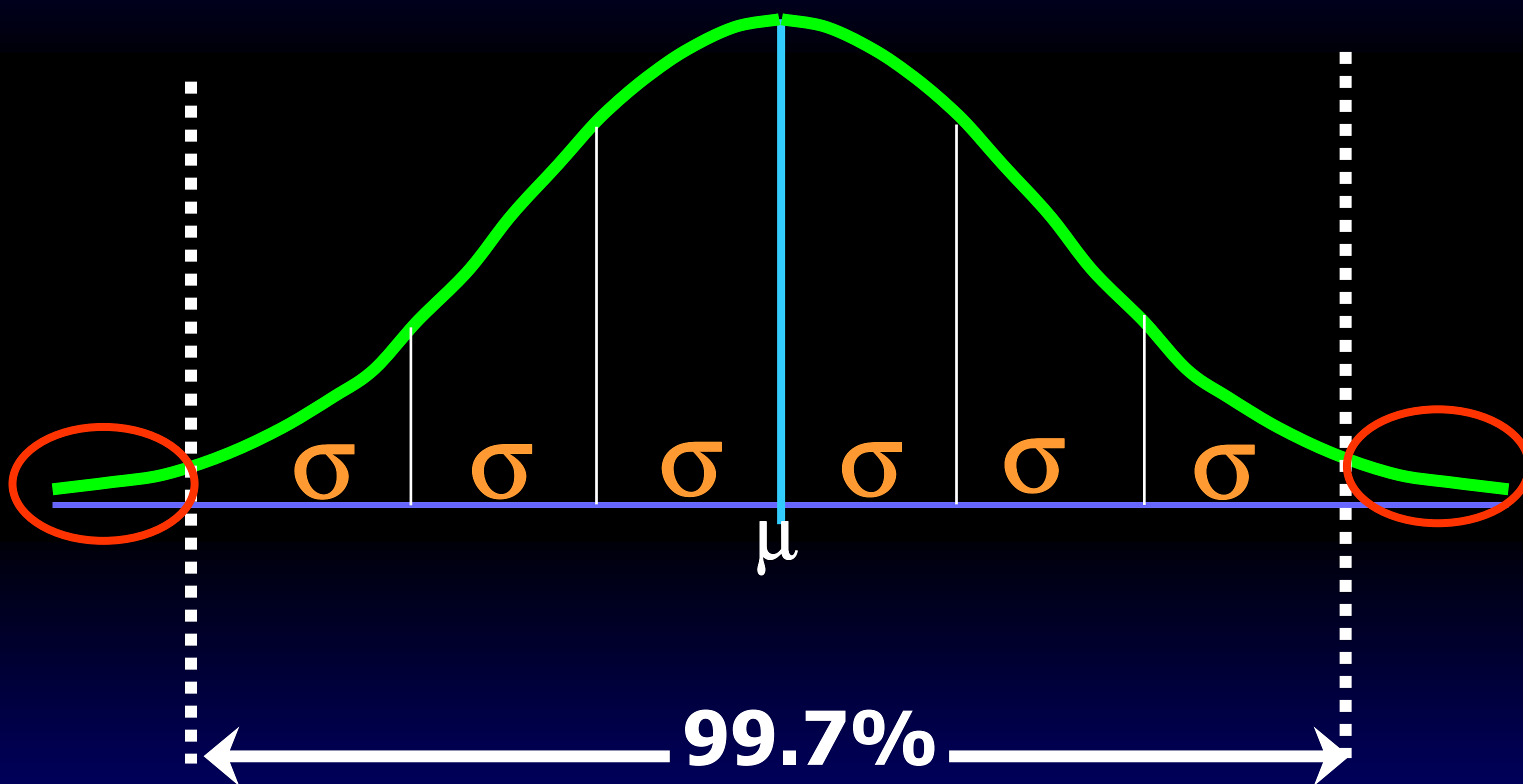
What percentage of the population data is outside of ±3σ?

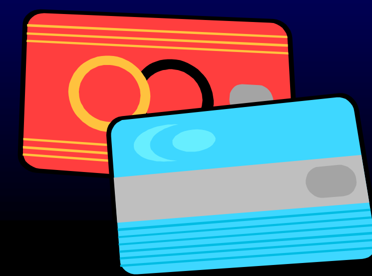


100% - 99.7% = .3%

0.3% doesn't sound bad – does it?

Lets look at a business example





Company processed 250,000 credit card bills/month

0.3% outside of customer specs on accuracy

750 unhappy customers every month due to accuracy

99.7% within spec may sound good, but it may not be good for the customer

Six Sigma . . . More Is Better!

99% Good (~ 4σ)

- 20,000 lost articles of mail per hour
- Unsafe drinking water for almost 15 minutes each day
- 5,000 incorrect surgical operations/week
- Two short or long landings at most major airports each day
- 200,000 wrong drug prescriptions/year
- No electricity for almost 7 hours/month

99.99966% Better (6σ)

- Seven articles lost per hour
- One unsafe minute of drinking water every seven months
- 1.7 incorrect operations/week
- One short or long landing every five years
- 68 wrong prescriptions/year
- One hour without electricity every 34 years

Performance Level	SIGMA	DPMO	
A+	6	3.4	World Class
A	5	233	Excellent
B	4	6,210	Good
C	3	66,811	Average
D	2	308,770	Below Average
F	1	697,672	Not Good

The DMAIC Methodology

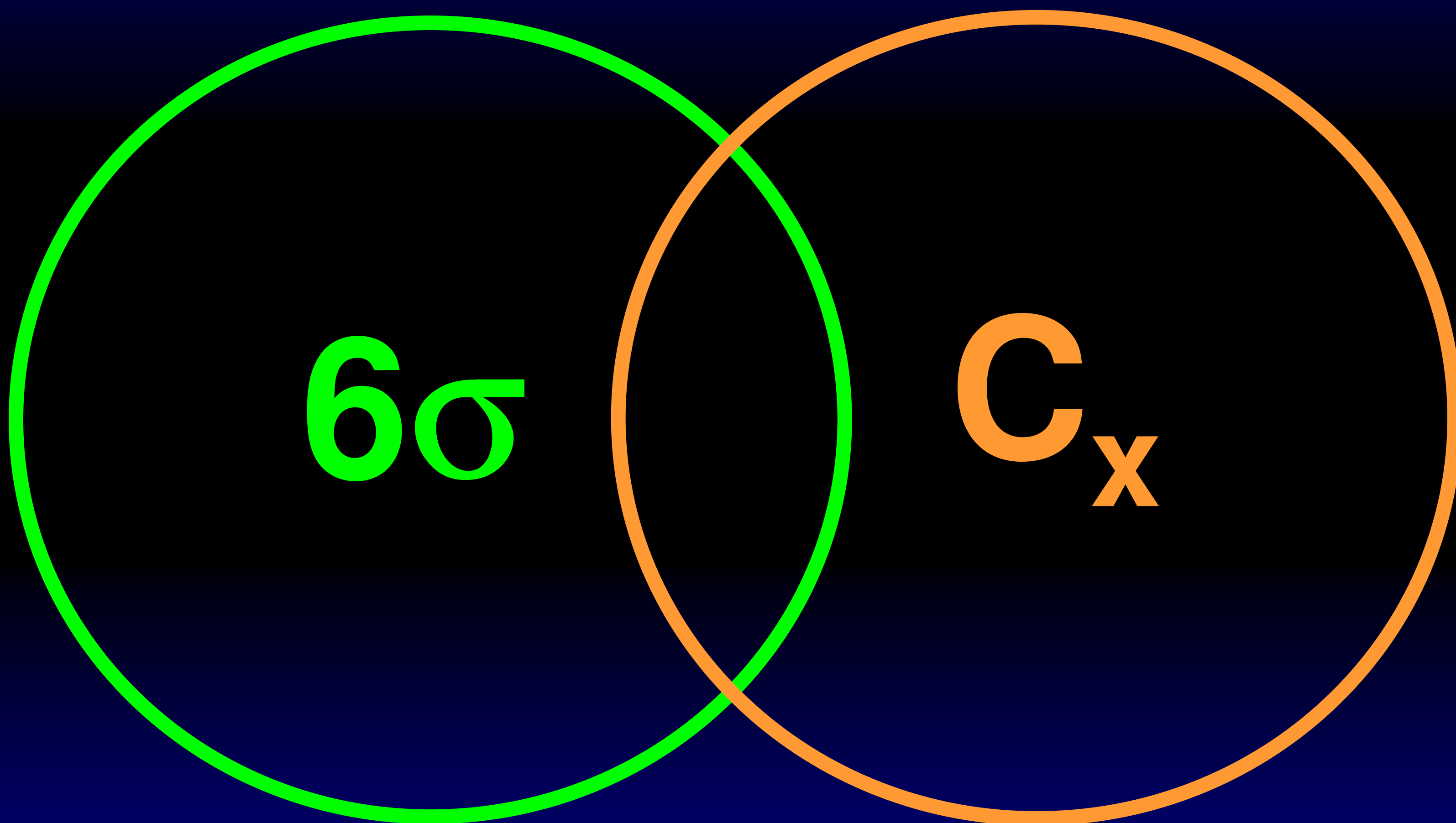
For Each Product or Process CTQ –

Define, Measure, Analyze, Improve,and Control

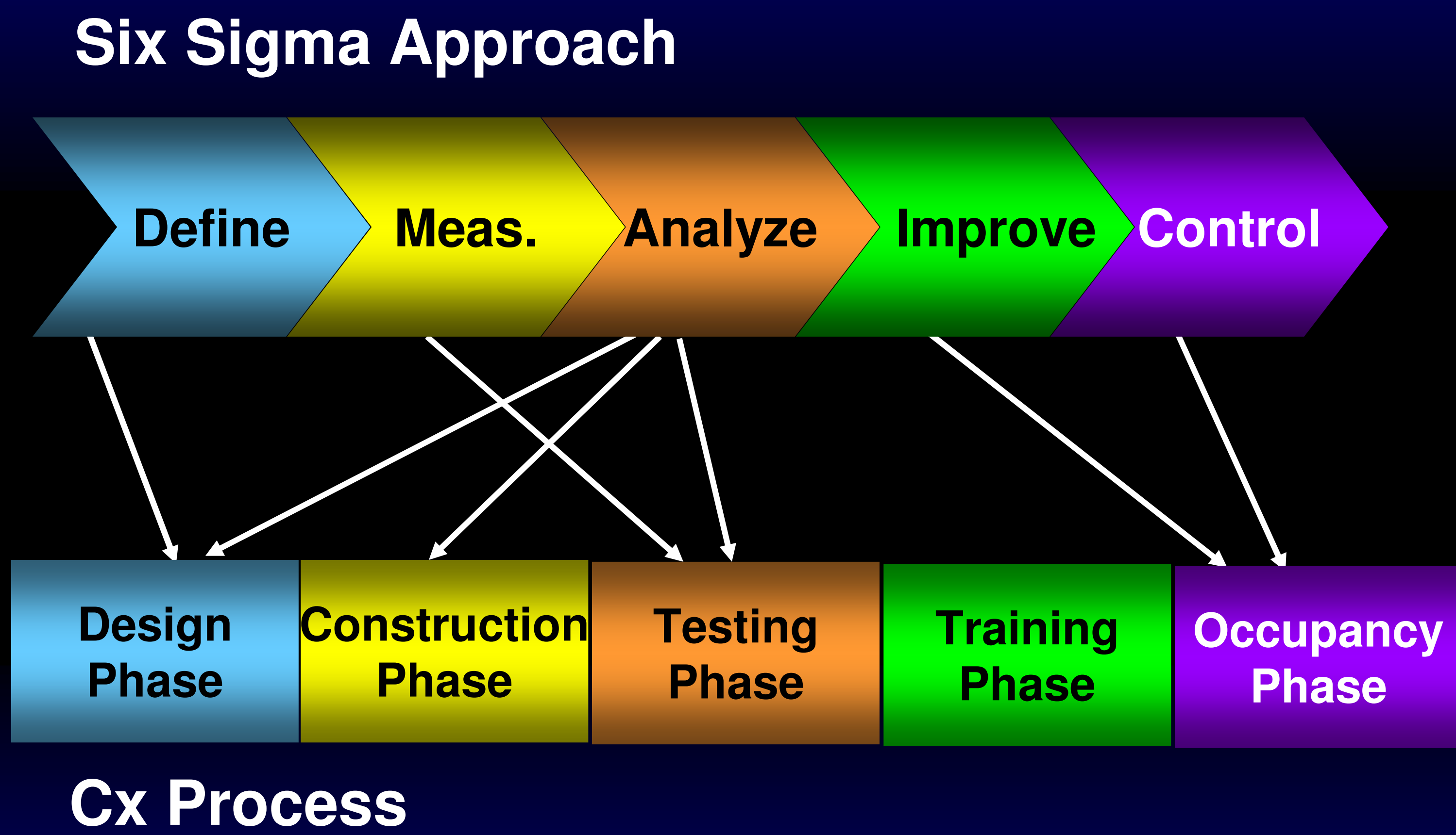
$$Y = f\,(x_1, x_2, \ldots, x_n)$$

Define	**What is the scope of the problem?**
Measure	**What is the frequency of defects?**
Analyze	**Where and why do defects occur?**
Improve	**How can we fix the process?**
Control	**How can we make the process stay fixed?**

Six Sigma Tools & Techniques Applied to Cx



Some of the Intersection Points

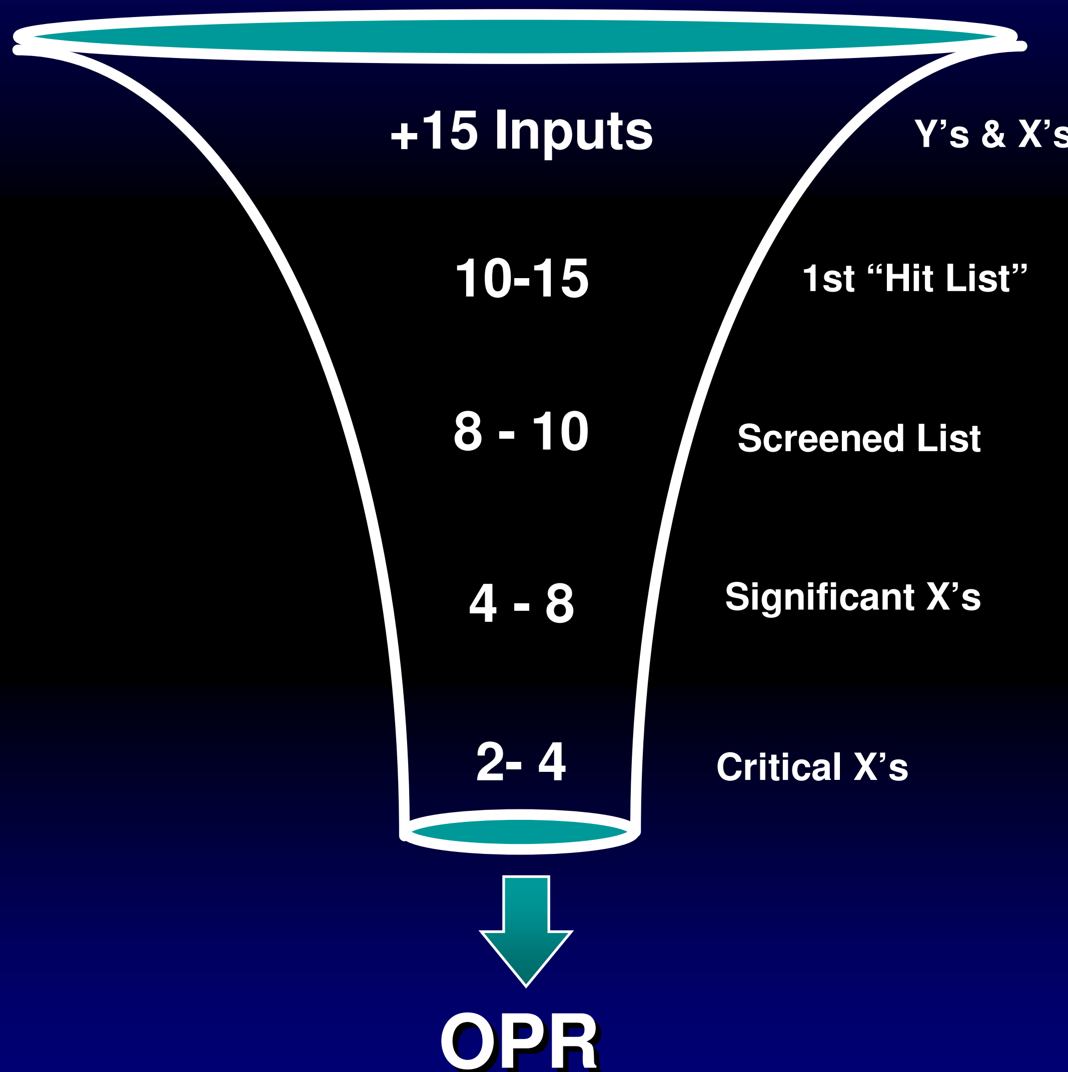


Start At The Beginning - Define

C_x	6σ
Owner's **P**roject **R**equirements	Project Charter CTQ Flowdown Cause & Effect Matrix SIPOC

What Is Our Objective?

- **Project Charter**
- Process Map
- CTQ Flowdown
- C&E Matrix



Five Major Elements of a Charter

- **Business Case**
  - ***Explanation of why to do the project***
- **Problem and Goal Statements**
  - ***Description of the problem/opportunity or objective in clear, concise, measurable terms***
- **Project Scope**
  - ***Process dimensions, available resources***
- **Milestones**
  - ***Key steps and dates to achieve goal***
- **Roles**
  - ***People, expectations, responsibilities***

Business Case Definition & Example

Project Title: Data Center Commissioning

Business Case:

(A broad definition of the issue as well as the rationale for why this project should be a business priority.)

Example: The company did not invest in commissioning two previous data centers. Those facilities experienced a number of start-up issues that resulted in cost/schedule overruns. Senior management is concerned about implications to their stock price of not commissioning the company's new flagship data center.

Problem Statement Definition & Example

Project Title: Data Center Commissioning

Problem/Opportunity Statement:
1 or 2 sentences describing the **symptoms** such as **where** is the problem **how big** is the problem, or **what is the impact**

Example: The two previous non-commissioned data centers had air distribution and delivery problems on the raised floor which reduced annual uptime by 20%. Cooling issues on the new center could potentially reduce uptime by 45% and cut revenues by 50%.

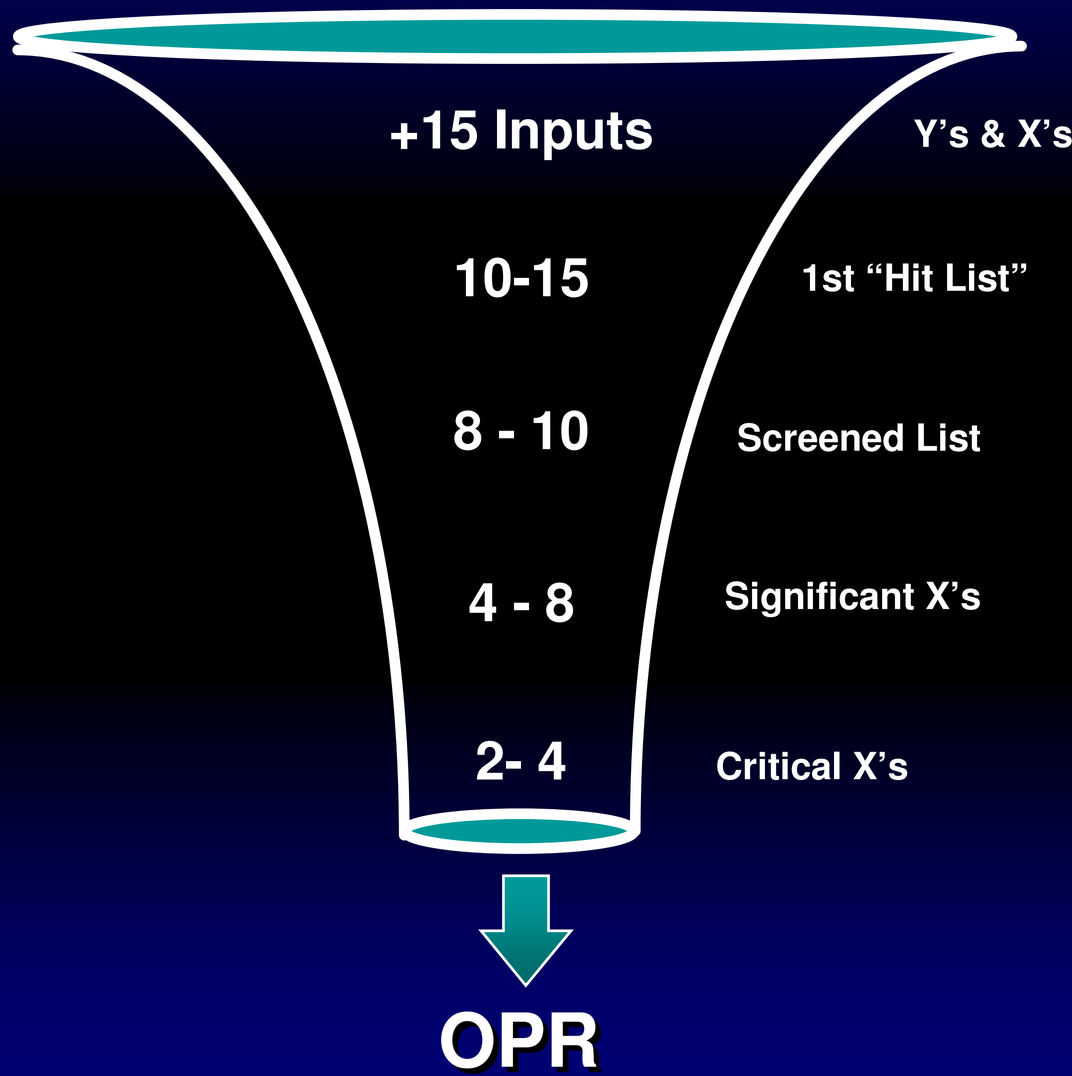
What Is Our Objective?

Project Charter

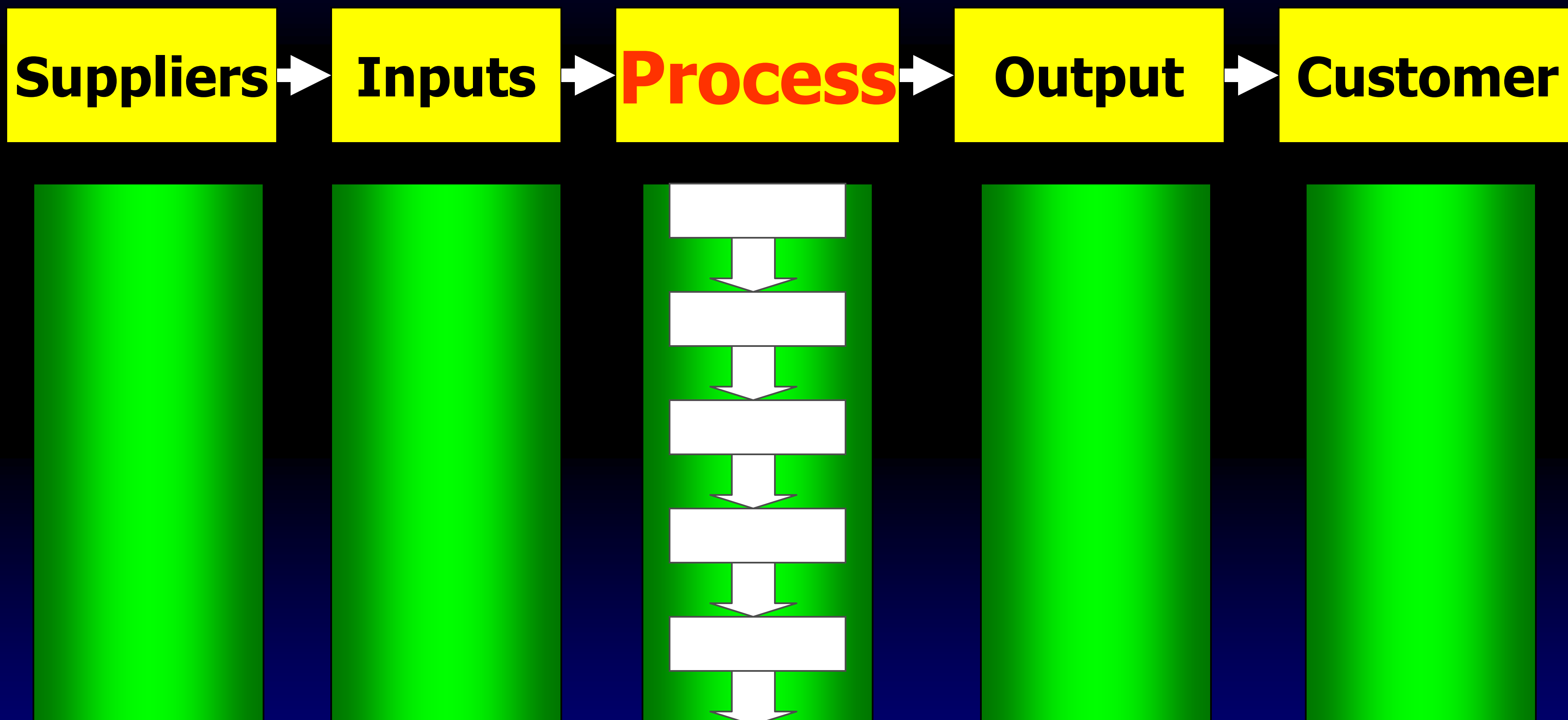
Process Map

CTQ Flowdown

C&E Matrix

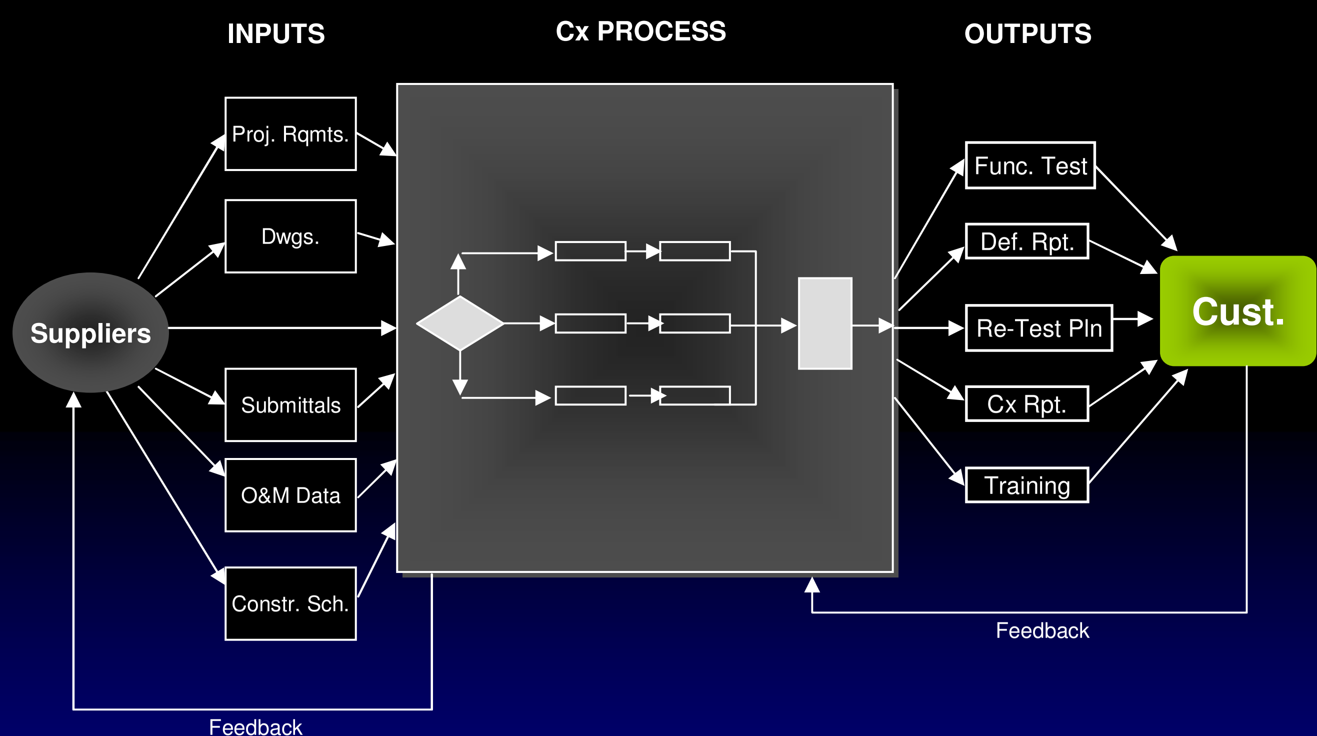


How Do You Identify What's Important? Start with SIPOC



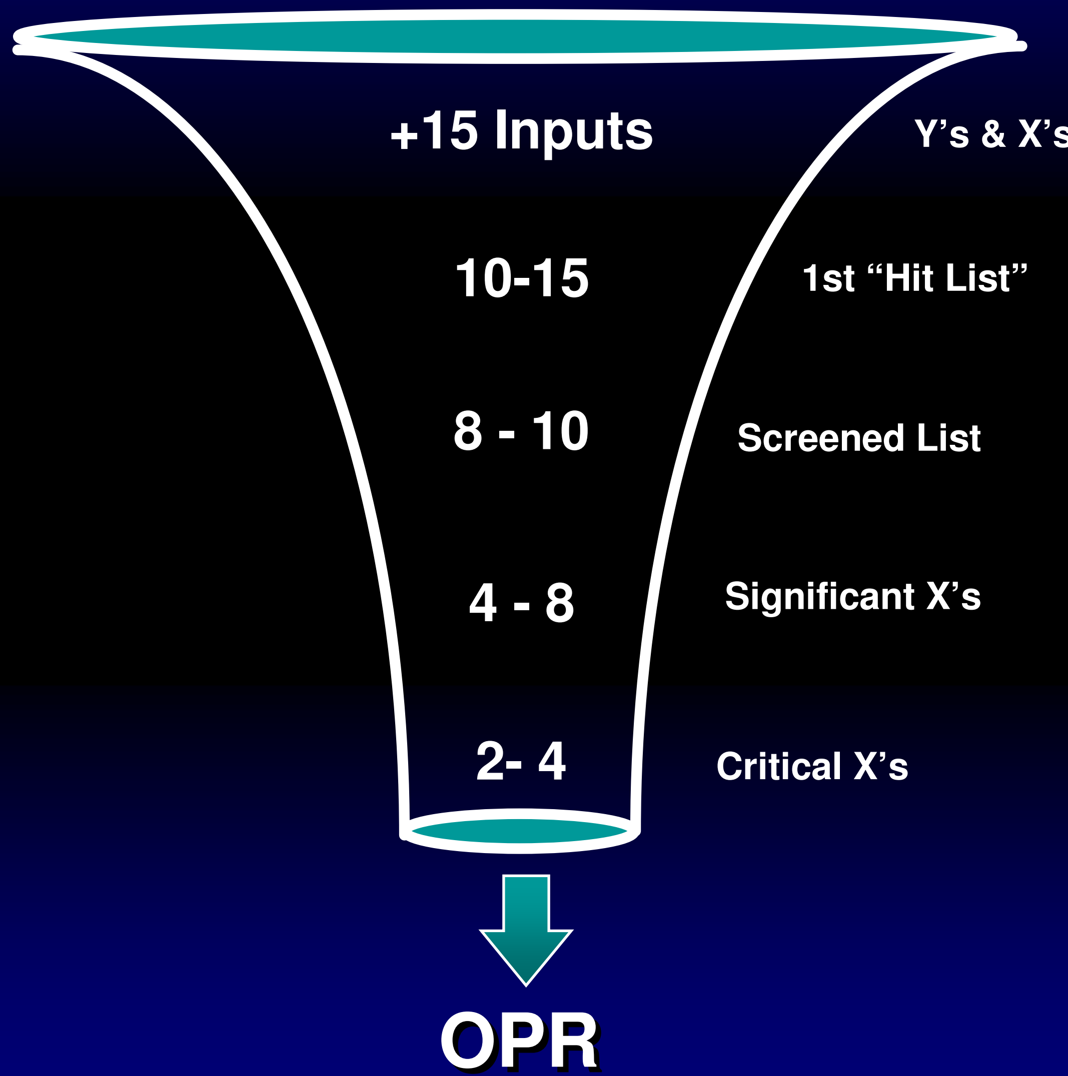
Creating a SIPOC

Suppliers	Inputs	Process	Outputs	Cust.
Providers of the process 6	Inputs into the process 5	Process Descrip. 1 Process Map 2	Outputs of the process 3	Receiver of the process outputs 4



What Is Our Objective?

- Project Charter
- Process Map
- CTQ Flowdown
- **C&E Matrix**



What Does It Do?

- **Prioritizes customer requirements (Y's)**
- **Calculates a customer "Pain" Index**
- **Screens Our X's - Prioritizes Steps and Inputs**

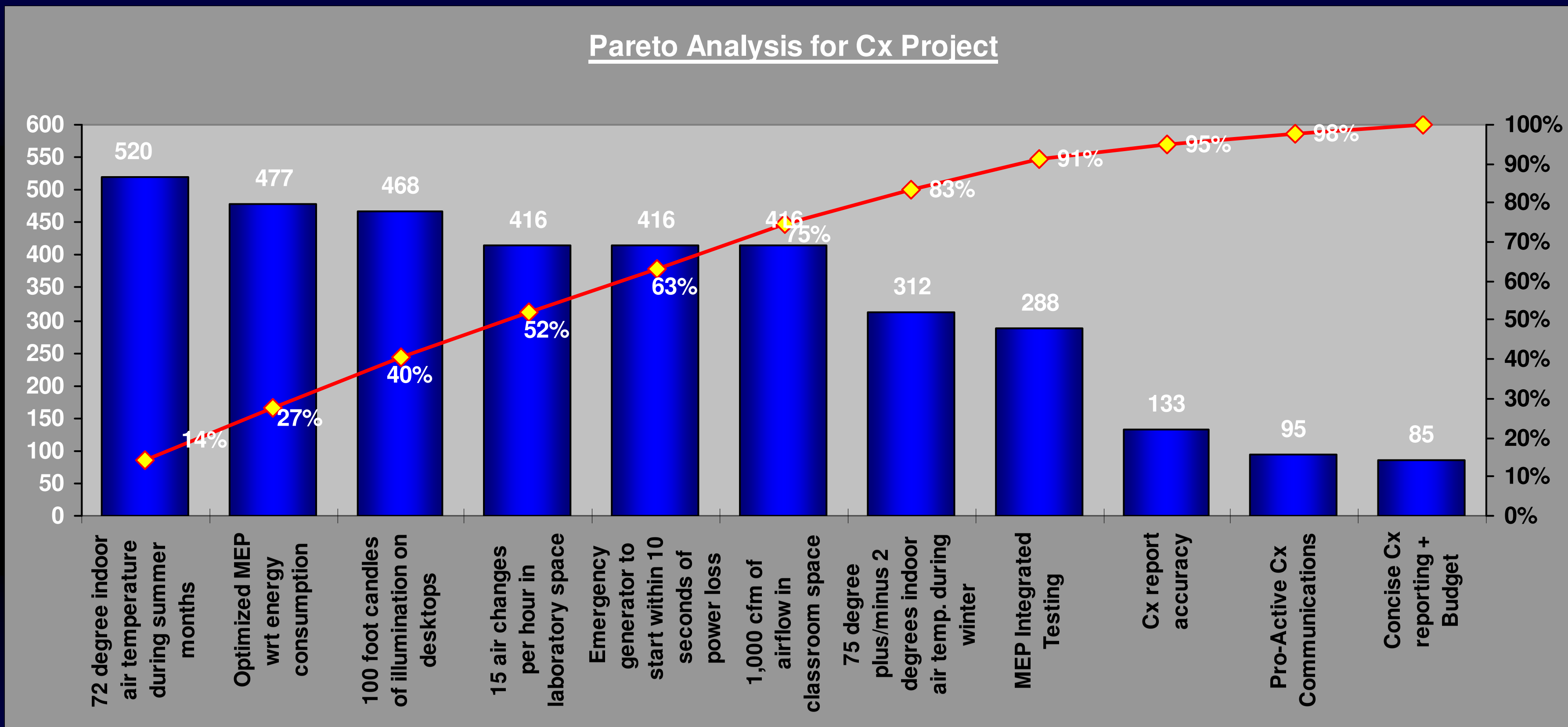
Cause & Effect Matrix Steps

- Identify key customer requirements (outputs) from Process Map
- Rank order and assign priority factor to each output (Usually on a 1 to 10 scale)
- Identify all process steps and materials (inputs) from the Process Map
- Evaluate correlation of each input to each output
  - **Low Score:** changes in the input variable (amount, quality, etc.) have small effect on output variable
  - **High Score:** changes in the input variable can greatly affect the output variable
- Cross multiply correlation values with priority factors and add across for each input

Example of C&E Matrix

			How CxA Can Impact the Customer CTQ										
		Importance Weighting (scale: 1 - 10)	Develop OPR	Review BOD for traceability to OPR	Develop Cx Plan	Design Reviews	Develop Cx Specifications to Flow into Contractor Bid Packages	Submittal Reviews	Construction Observations	Review Pre-Functional Checklists	Functional Testing	Operator Training	
	Totals:		521	486	342	316	313	289	139	215	723	282	
	Owner CTQ (i.e., Customer Expectation): Science/Tech Facility												
1	72 degree indoor air temperature during summer months	10	9	9	4	4	4	4	1	4	9	4	520
2	100 foot candles of illumination on desktops	9	9	9	4	4	4	4	1	4	9	4	468
3	15 air changes per hour in laboratory space	8	9	9	4	4	4	4	1	4	9	4	416
4	75 degree plus/minus 2 degrees indoor air temp. during winter	6	9	9	4	4	4	4	1	4	9	4	312
5	Emergency generator to start within 10 seconds of power loss	8	9	9	4	4	4	4	1	4	9	4	416
6	Cx report accuracy	7	0	0	9	0	0	0	0	1	9	0	133
7	Concise Cx reporting	3	0	0	1	1	0	4	9	4	4	0	69
8	MEP Integrated Testing	9	4	1	4	4	9	0	1	0	9	0	288
9	Optimized MEP wrt energy consumption	9	4	4	4	9	4	9	1	0	9	9	477
10	Cx Budget Compliance	8	1	0	1	0	0	0	0	0	0	0	16
11	Pro-Active Cx Communications	5	0	0	0	0	0	0	9	0	9	1	95
12	1,000 cfm of airflow in classroom space	8	9	9	4	4	4	4	1	4	9	4	416

C&E Flows Right Into Pareto Chart



Moving Forward - Analyze

Retro-C_x

Where Are The Potential Areas of Variation?

6σ

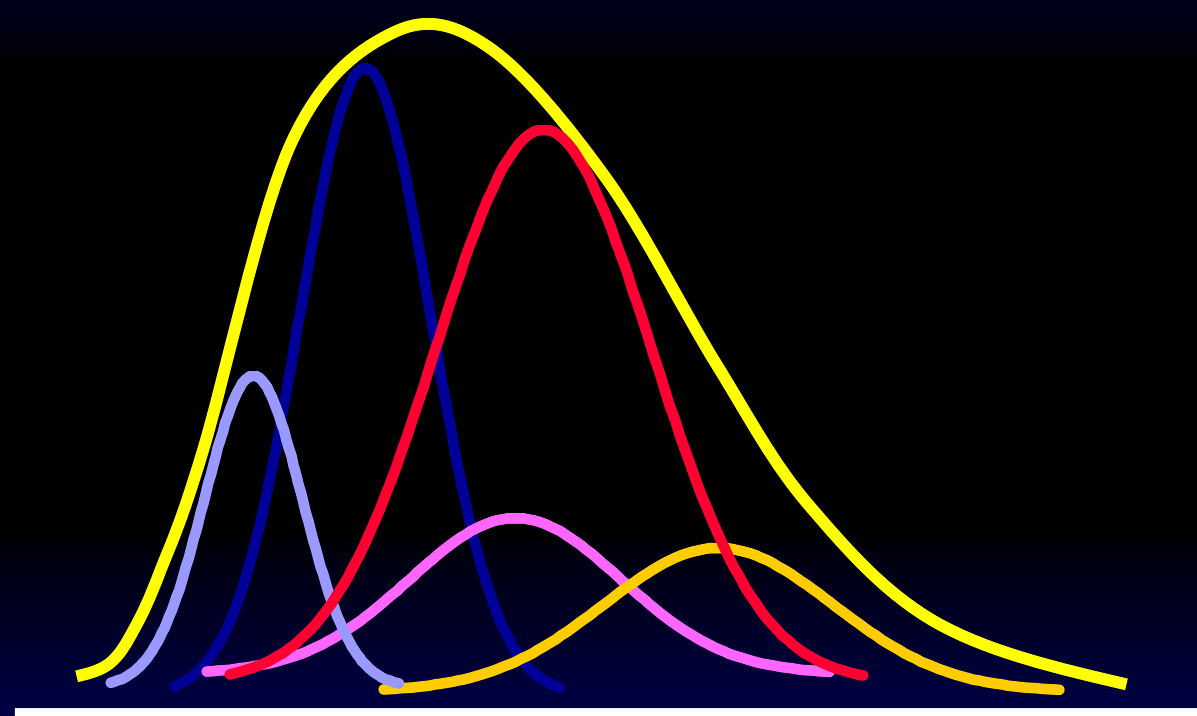
Establish Process Capability

Define Performance Objective

Identify Variation Sources

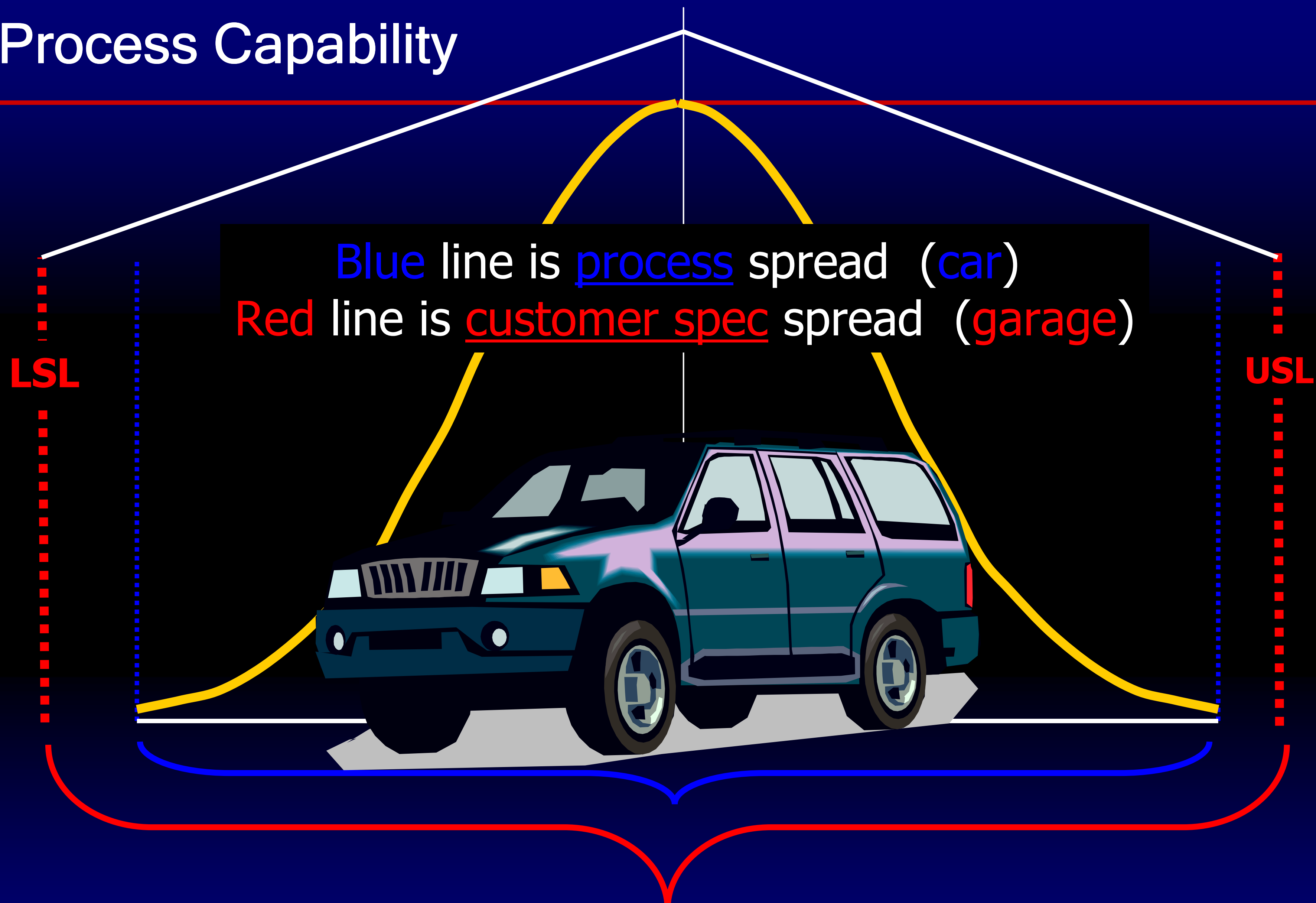
Remember

A Process is
“A Distribution of Distributions”



Variation is the problem

Process Capability

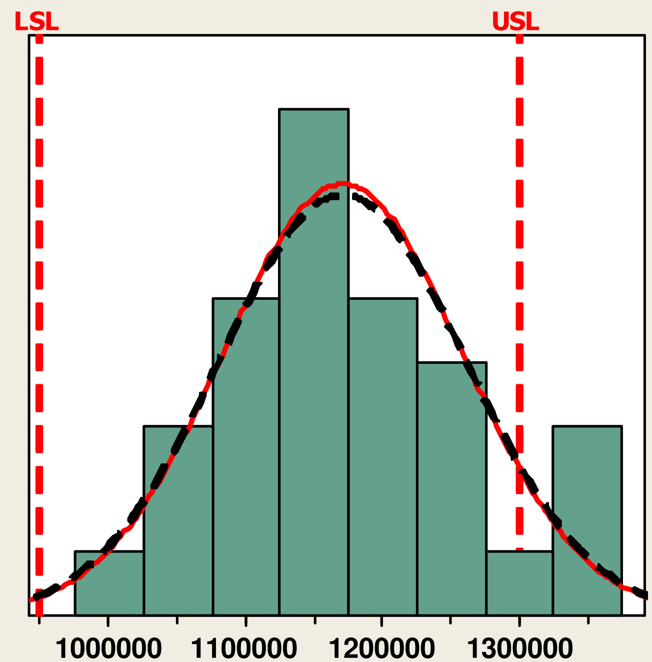


Pp measures how wide the garage is!
Ppk indicates how well you park the car – is it centered?

Process Capability Example

Aggregate kWH for all three Electric Meters

Process Data	
LSL	950000
Target	*
USL	1.3e+006
Sample Mean	1.17085e+006
Sample N	30
StDev(Within)	87894.4
StDev(Overall)	90086.1



— Within
– – Overall

Potential (Within) Capability	
Cp	**0.66**
CPL	**0.84**
CPU	**0.49**
Cpk	**0.49**

Overall Capability	
Pp	**0.65**
PPL	**0.82**
PPU	**0.48**
Ppk	**0.48**
Cpm	*

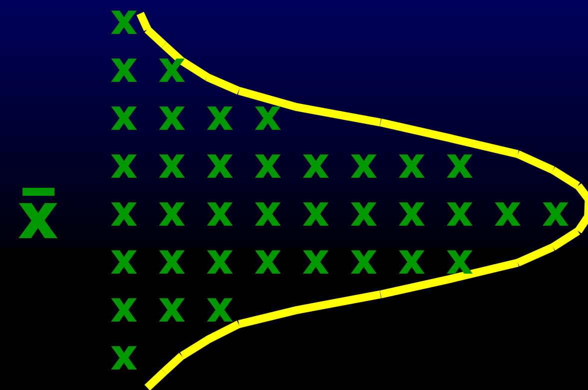
Observed Performance	
PPM < LSL	0.00
PPM > USL	100000.00
PPM Total	100000.00

Exp. Within Performance	
PPM < LSL	5990.33
PPM > USL	70870.32
PPM Total	76860.65

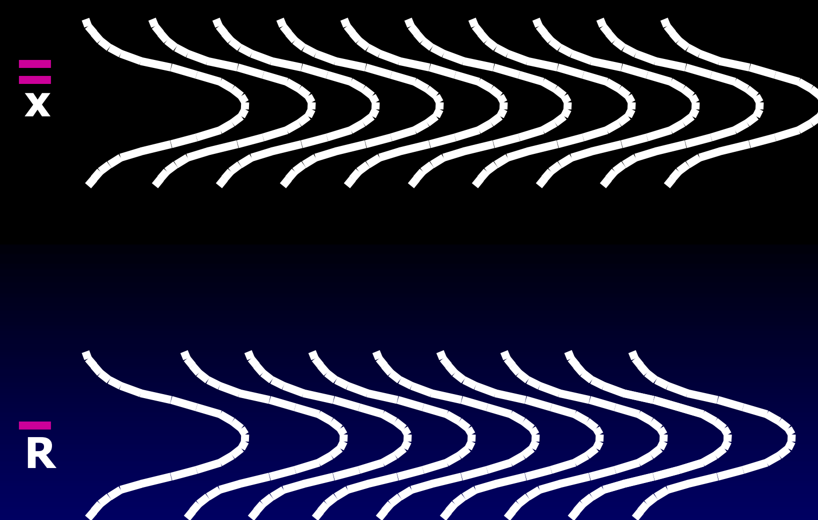
Exp. Overall Performance	
PPM < LSL	7111.53
PPM > USL	75844.49
PPM Total	82956.02

Control chart vs. frequency distribution

Snapshot

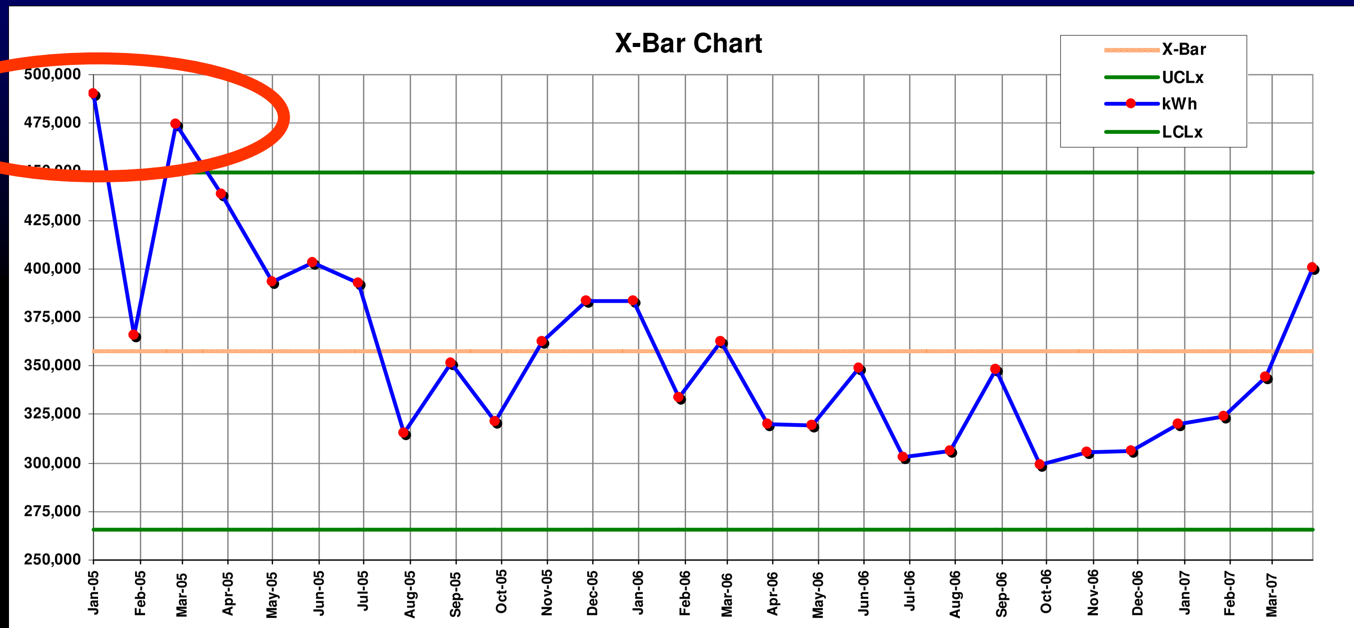


Moving picture

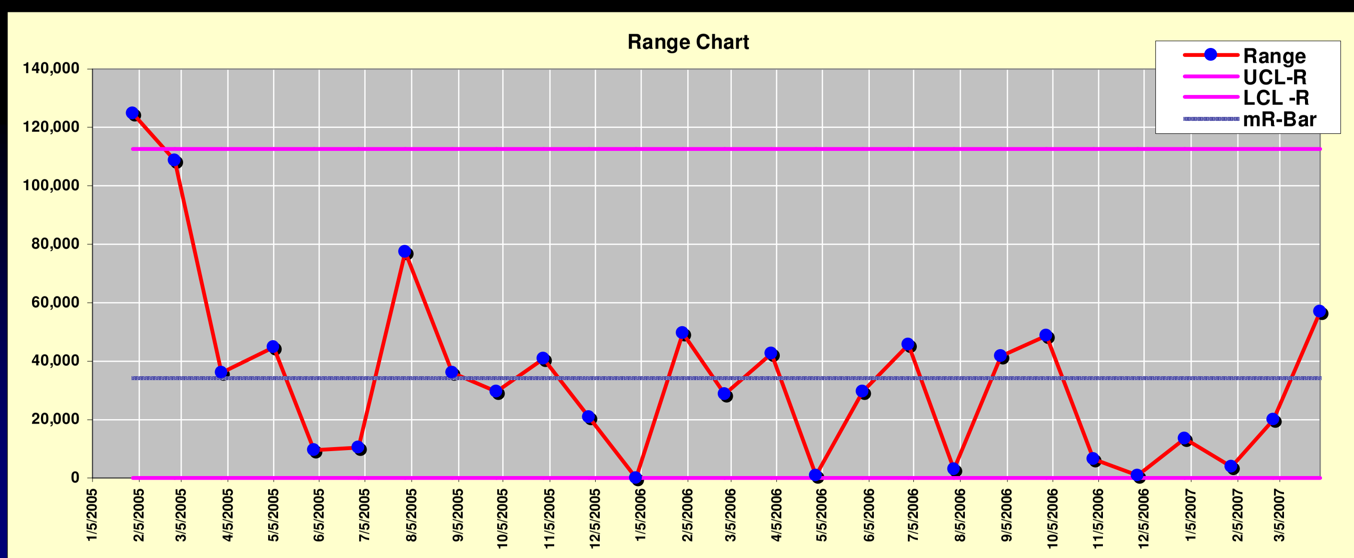


Detect and monitor process variation over time

Look For Variation Sources: Control Chart (kWH/month)



Points Outside Control Limits

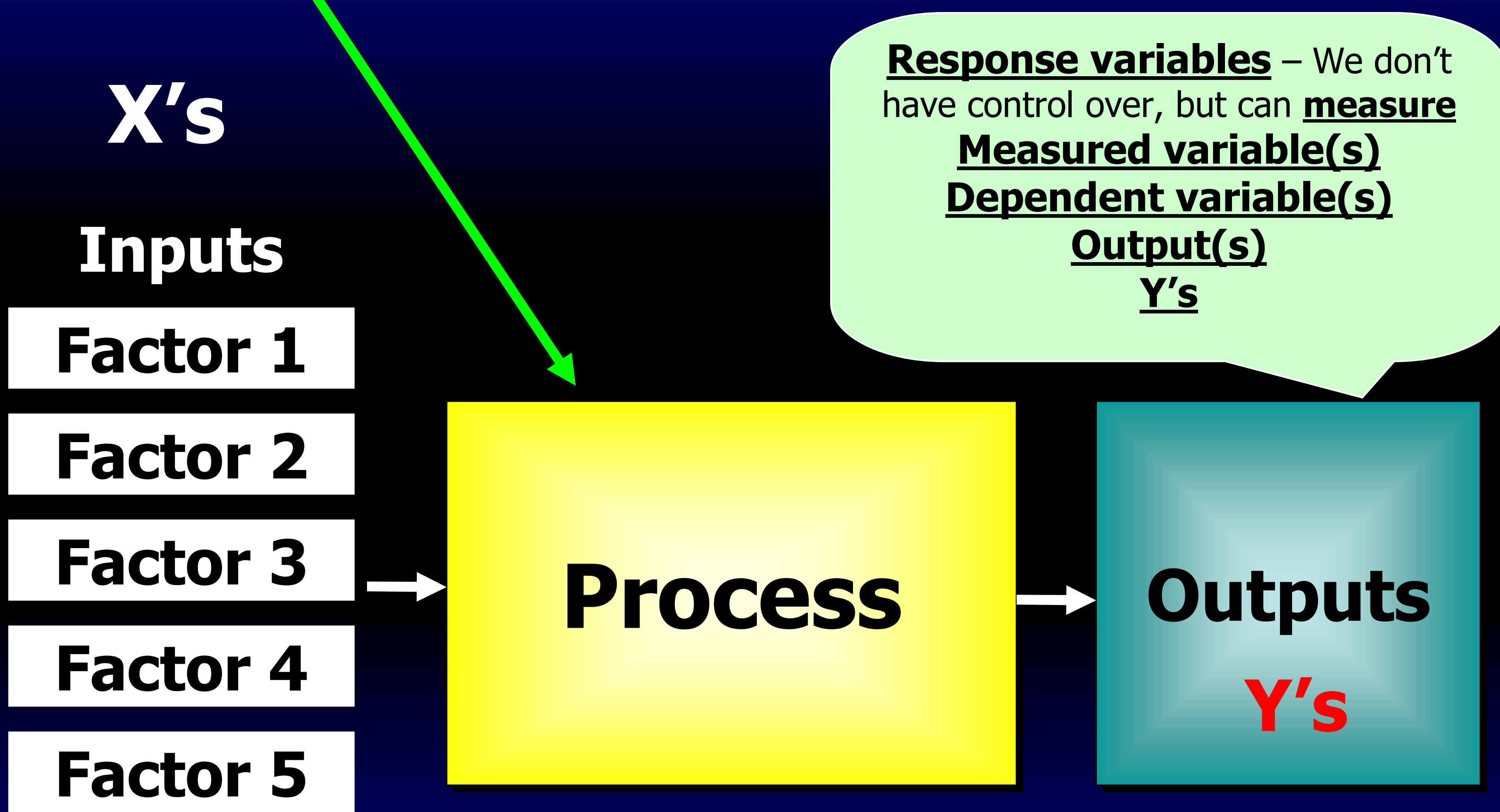


6σ

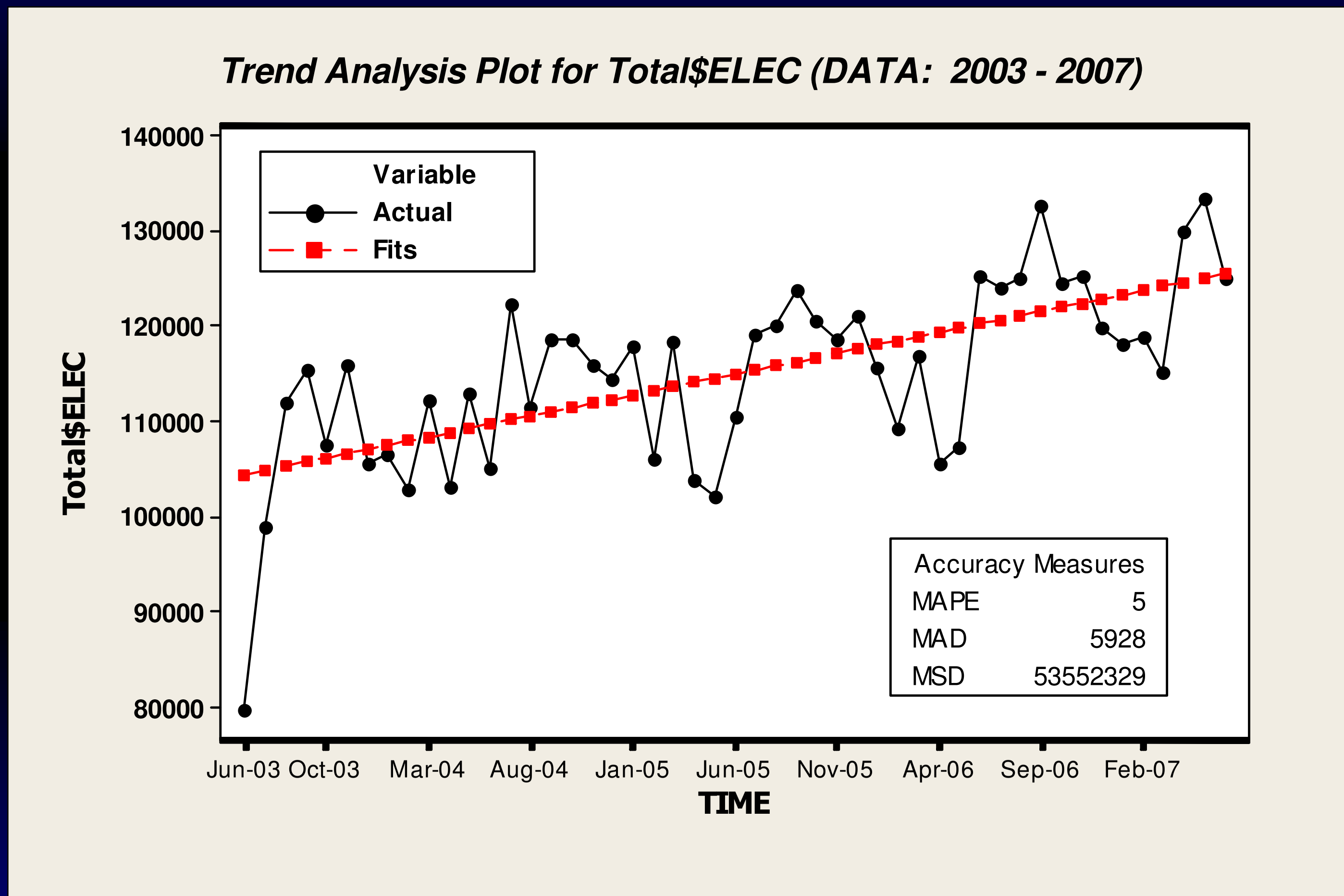
C_x

CASE STUDY

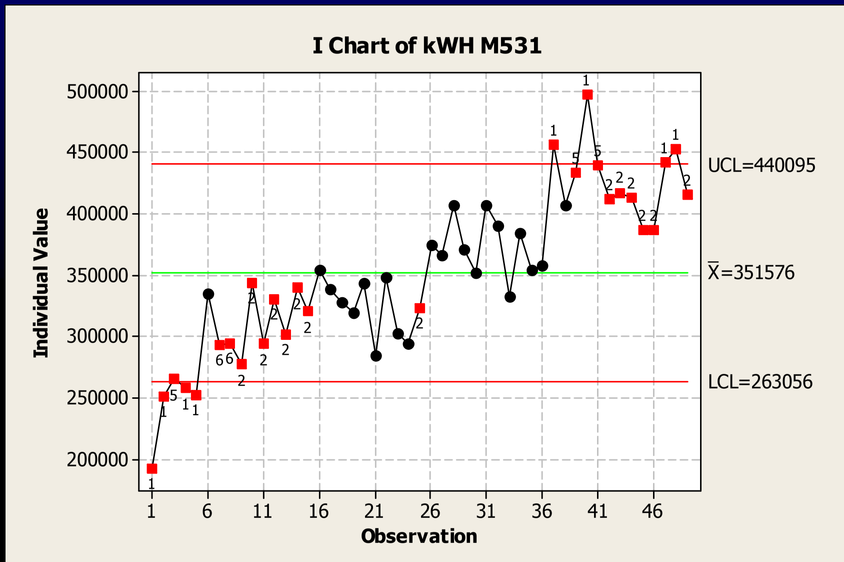
The MEP Is The Facility's Process

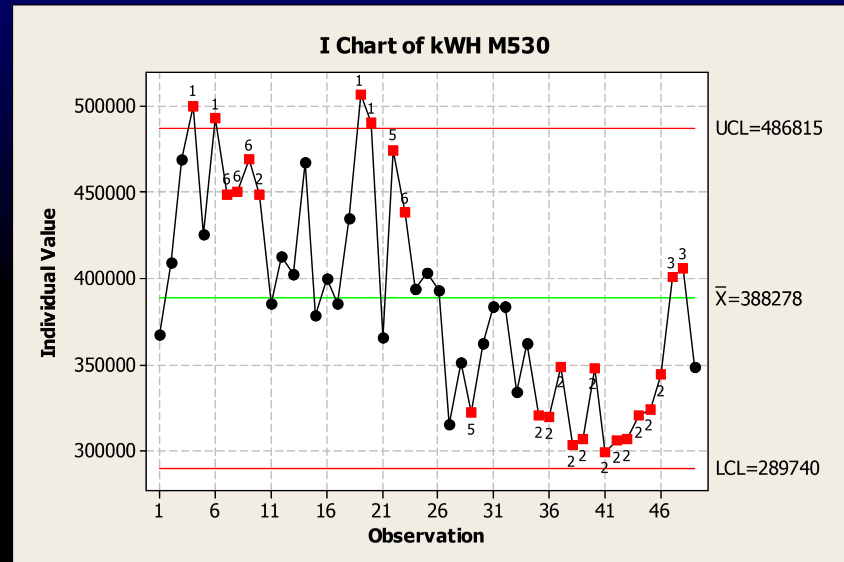


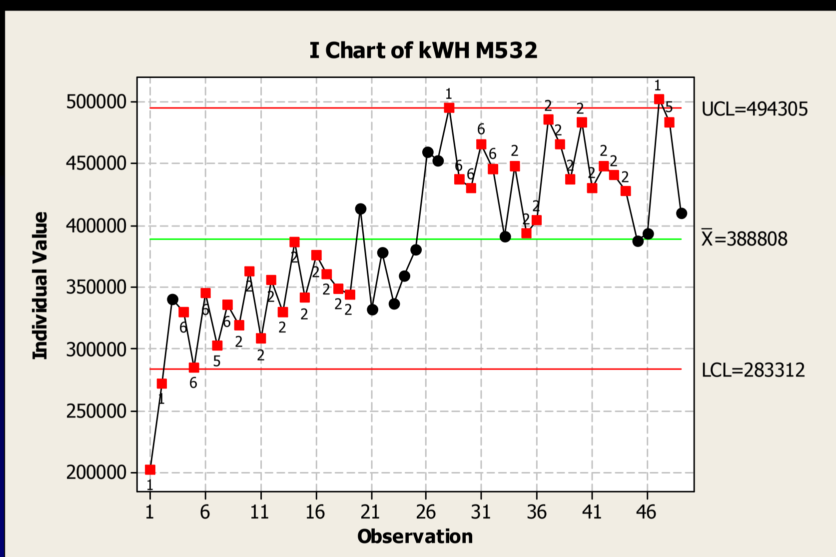
We Started By Looking At Some General Trends

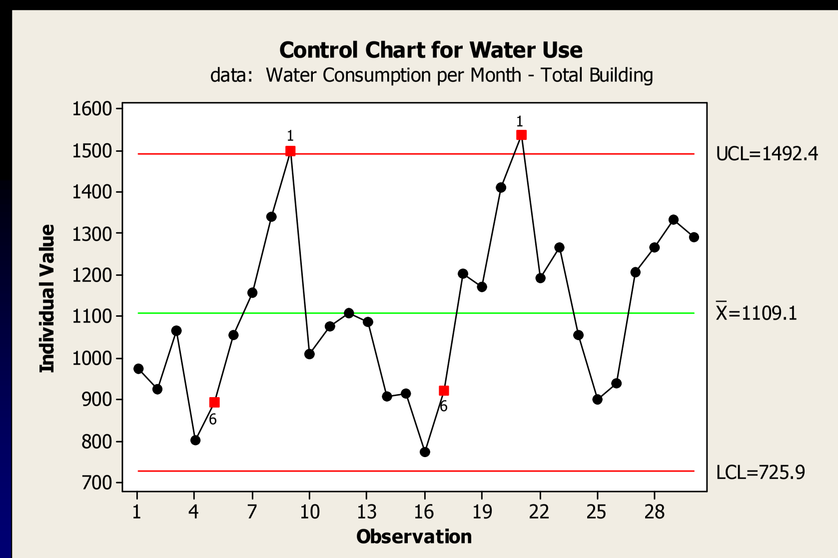


Looked For Clues To “Special Cause” Variation

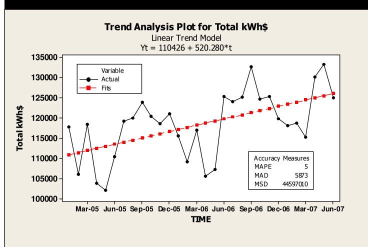








MGM Tower Cx Project Charter



Business Case:

Executive management has decided to pursue LEED Certification for the ________ in Los Angeles. It is desired to have the facility stand out as a "Model" facility that sets the standard. To that end, in addition to meeting the requirements for LEED certification, improving the energy performance of the facility is an objective that is desired for tenant retention.

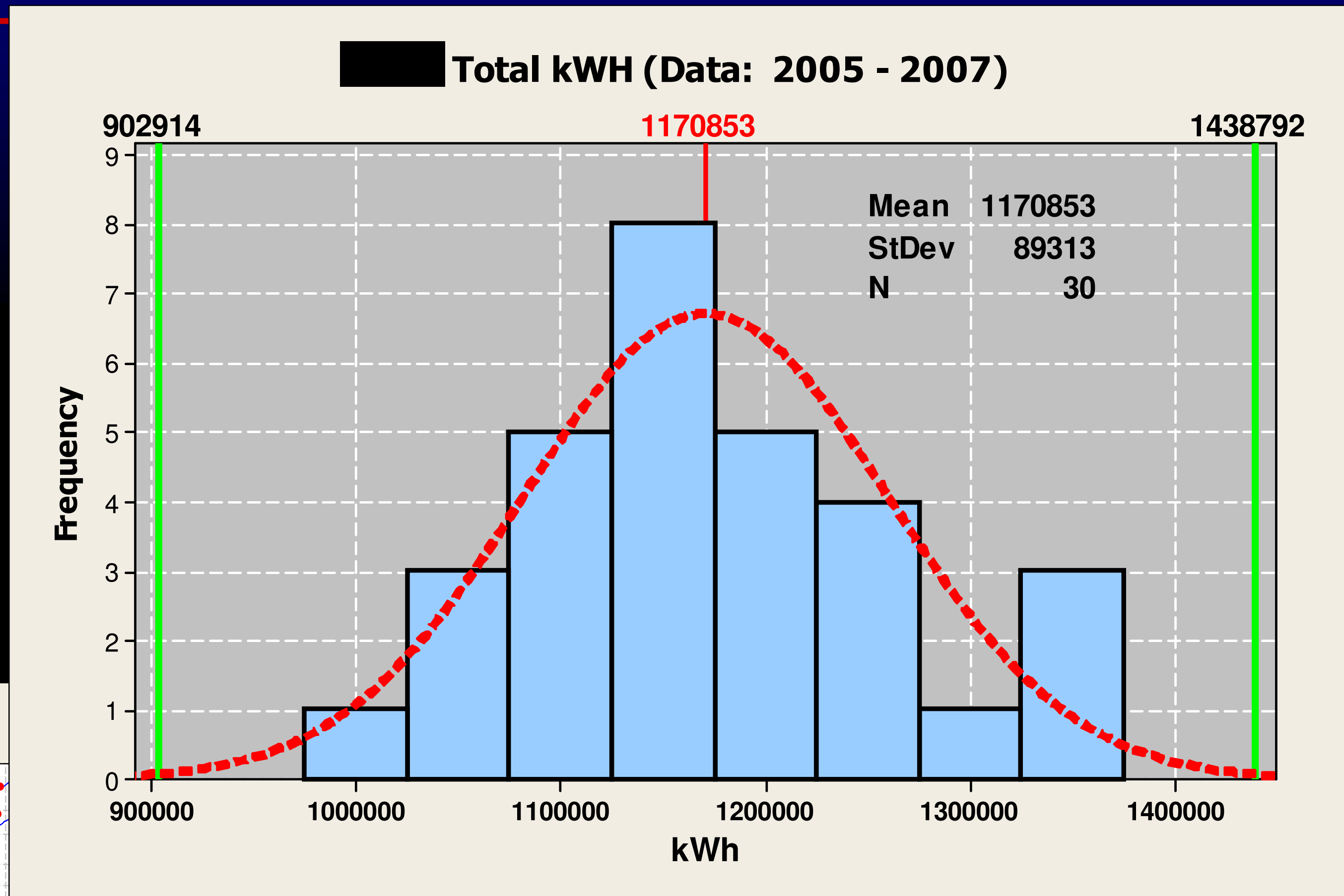
Problem Statement:

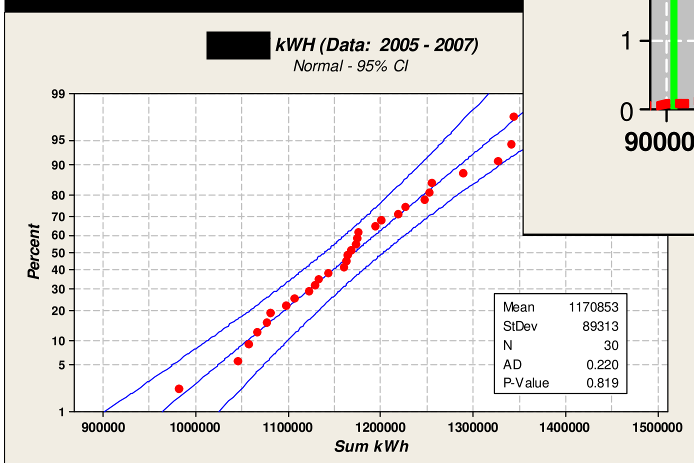
It appears that the HVAC process is currently operating at a 1.4 Sigma level. This performance manifests itself in energy cost. Hence, electricity cost has increased by an average of 7.2% from 2005 to 2007 increasing the incremental energy cost for the facility by $4,000 on an annual basis.

Goal Statement:

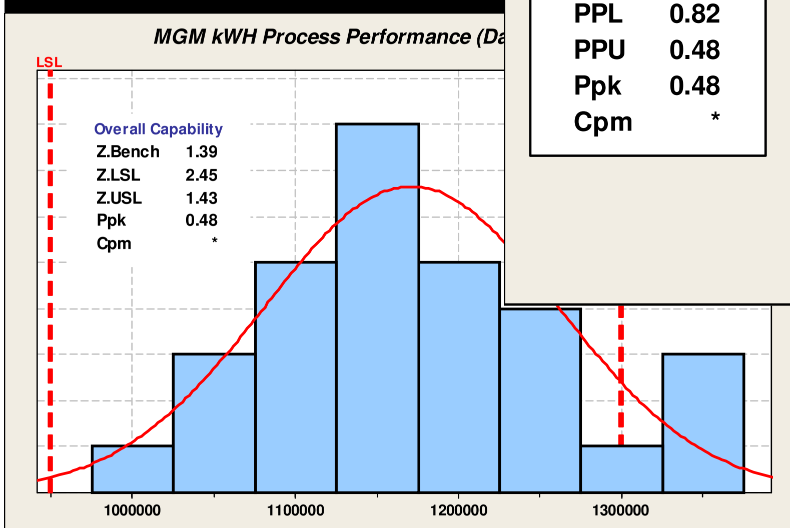
tbd.

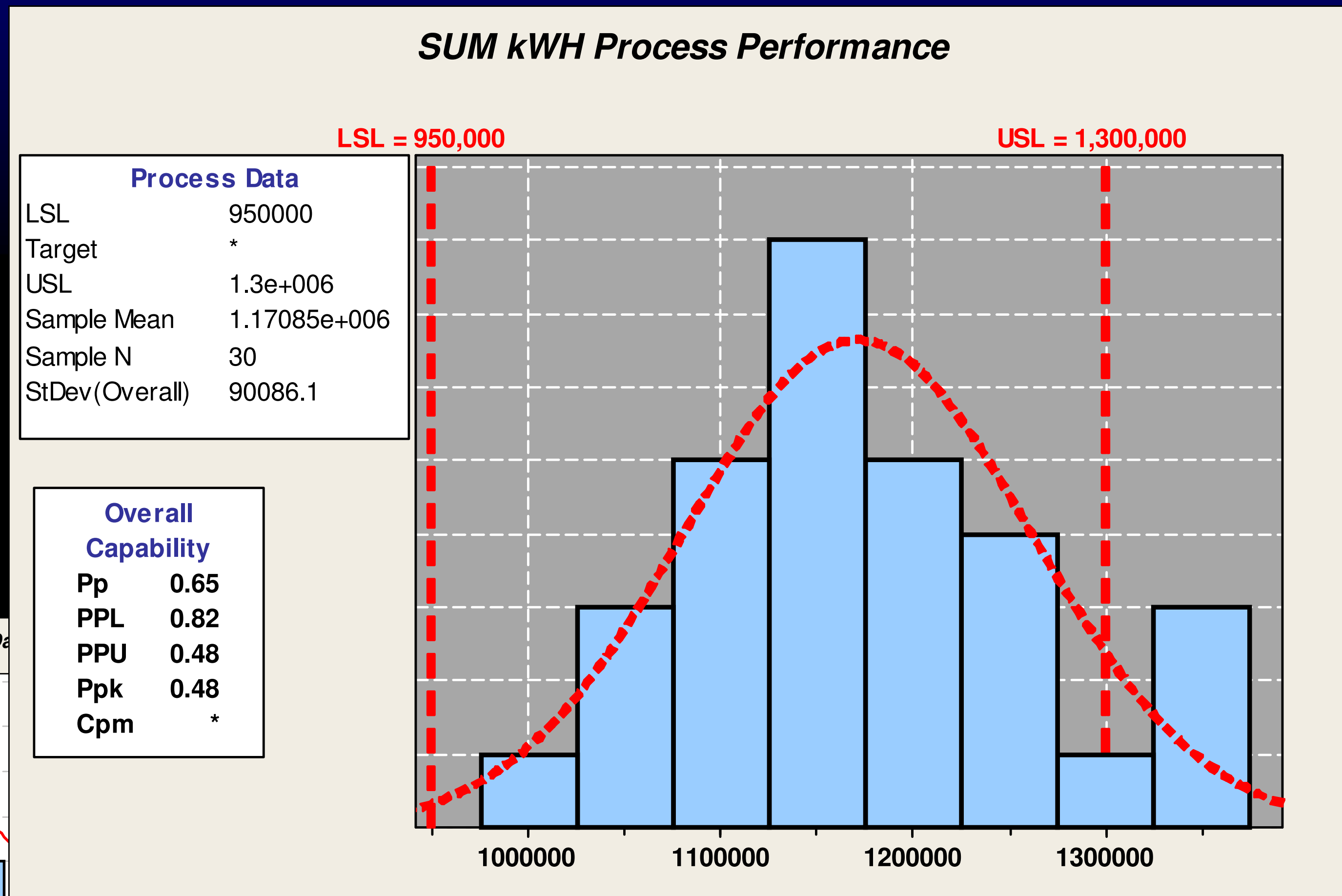
Total kWH (Data 2005 - 2007)



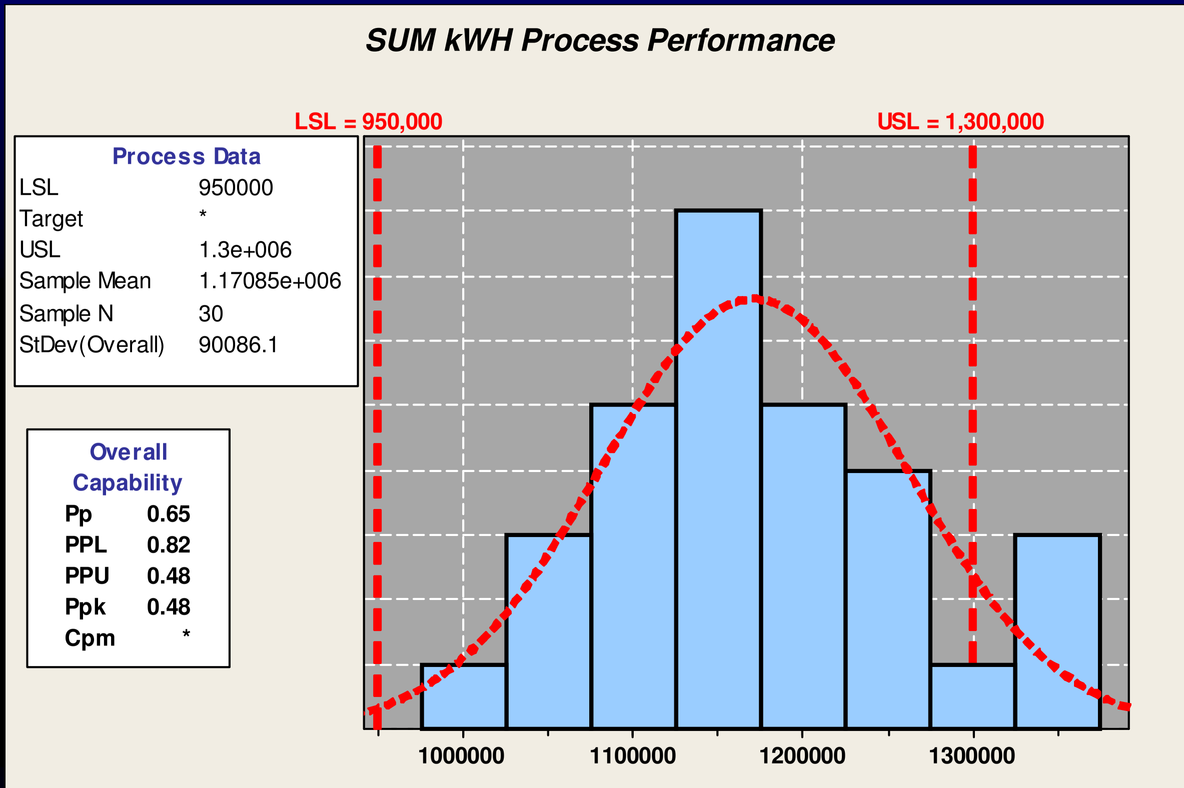


kWH Process Performance (Data: 2005 - 2007)





Process Capability - kWH



Random? Yes No

Capable? Yes No

Centered? Yes No

Acceptable? Yes No

Sigma Level (i.e., Z Bench) is ~ 1.4 - this is equivalent to 539,800 DPMO over the long term.

Process Performance: **Pp = 0.65**

Specs are only 65% of the Process Spread . . . Car doesn't fit in the garage. Good target value is 1.5

Process Centering: **Ppk = 0.48**

Process is not centered. Process is centered when **Ppk = Pp**.

Conclusion:

- Commissioning is a quality process
- Six Sigma is a process improvement methodology
- End goal is to delight the customer/client

Questions?

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