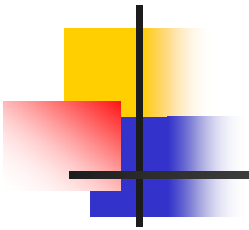


PROCESS CAPABILITY

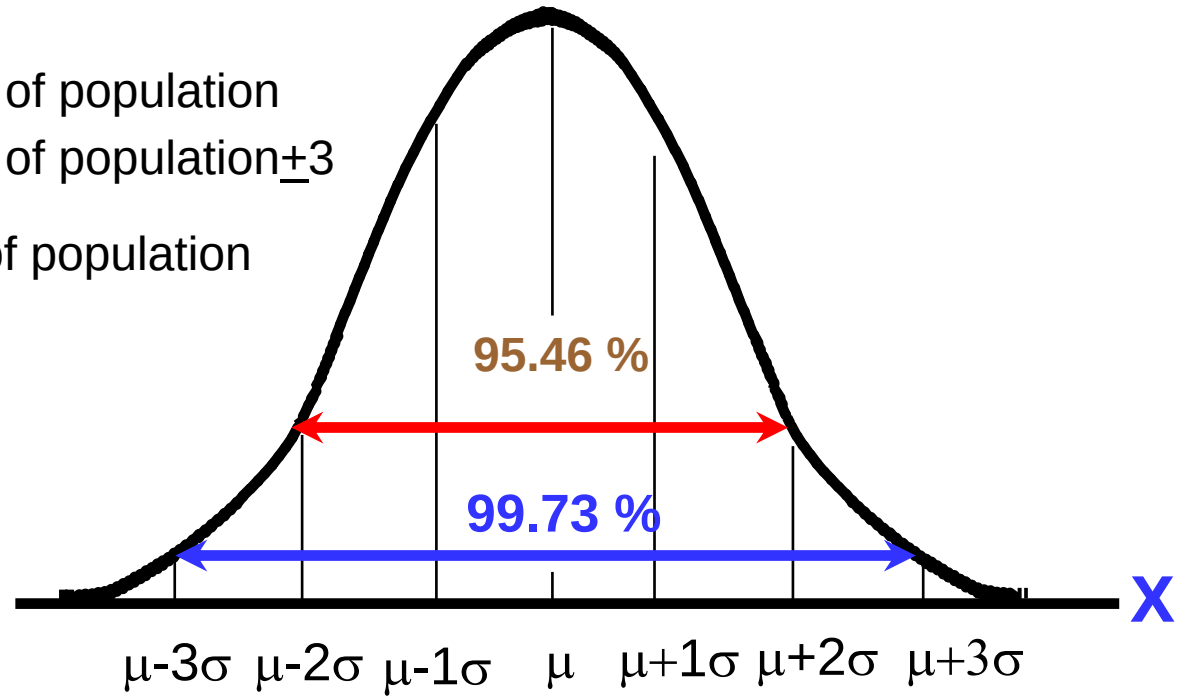
Muhammad Asif

The Normal Distribution

±1 S.D, 68% of population

±2 S.D, 95% of population±3

S.D, 99.7% of population



At 3-sigma away from process mean expect 99.73% of observations fall within these limits. At ±2σ expect 95.46%

Z- DISTRIBUTION TABLE

	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	0	0.004	0.008	0.012	0.016	0.0199	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714	0.0753
0.2	0.0793	0.0832	0.0871	0.091	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
0.3	0.1179	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.148	0.1517
0.4	0.1554	0.1591	0.1628	0.1664	0.17	0.1736	0.1772	0.1808	0.1844	0.1879
0.5	0.1915	0.195	0.1985	0.2019	0.2054	0.2088	0.2123	0.2157	0.219	0.2224
0.6	0.2257	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.2486	0.2517	0.2549
0.7	0.258	0.2611	0.2642	0.2673	0.2704	0.2734	0.2764	0.2794	0.2823	0.2852
0.8	0.2881	0.291	0.2939	0.2967	0.2995	0.3023	0.3051	0.3078	0.3106	0.3133
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.334	0.3365	0.3389
1	0.3413	0.3438	0.3461	0.3485	0.3508	0.3531	0.3554	0.3577	0.3599	0.3621
1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.377	0.379	0.381	0.383
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.398	0.3997	0.4015
1.3	0.4032	0.4049	0.4066	0.4082	0.4099	0.4115	0.4131	0.4147	0.4162	0.4177
1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4357	0.437	0.4382	0.4394	0.4406	0.4418	0.4429	0.4441
1.6	0.4452	0.4463	0.4474	0.4484	0.4495	0.4505	0.4515	0.4525	0.4535	0.4545
1.7	0.4554	0.4564	0.4573	0.4582	0.4591	0.4599	0.4608	0.4616	0.4625	0.4633
1.8	0.4641	0.4649	0.4656	0.4664	0.4671	0.4678	0.4686	0.4693	0.4699	0.4706
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.475	0.4756	0.4761	0.4767
2	0.4772	0.4778	0.4783	0.4788	0.4793	0.4798	0.4803	0.4808	0.4812	0.4817
2.1	0.4821	0.4826	0.483	0.4834	0.4838	0.4842	0.4846	0.485	0.4854	0.4857
2.2	0.4861	0.4864	0.4868	0.4871	0.4875	0.4878	0.4881	0.4884	0.4887	0.489
2.3	0.4893	0.4896	0.4898	0.4901	0.4904	0.4906	0.4909	0.4911	0.4913	0.4916
2.4	0.4918	0.492	0.4922	0.4925	0.4927	0.4929	0.4931	0.4932	0.4934	0.4936
2.5	0.4938	0.494	0.4941	0.4943	0.4945	0.4946	0.4948	0.4949	0.4951	0.4952
2.6	0.4953	0.4955	0.4956	0.4957	0.4959	0.496	0.4961	0.4962	0.4963	0.4964
2.7	0.4965	0.4966	0.4967	0.4968	0.4969	0.497	0.4971	0.4972	0.4973	0.4974
2.8	0.4974	0.4975	0.4976	0.4977	0.4977	0.4978	0.4979	0.4979	0.498	0.4981
2.9	0.4981	0.4982	0.4982	0.4983	0.4984	0.4984	0.4985	0.4985	0.4986	0.4986
3	0.4987	0.4987	0.4987	0.4988	0.4988	0.4989	0.4989	0.4989	0.499	0.499

Process Capability

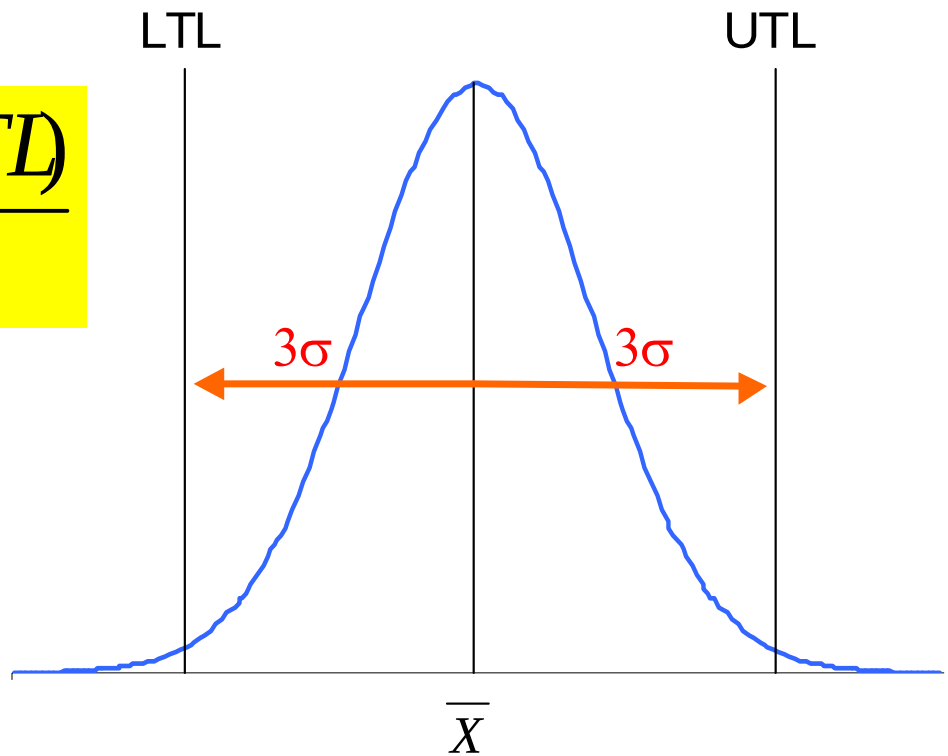
The ability of a process to meet product design/technical specifications

Conducted only when the process is normally distributed

HOW TO MEASURE Cp

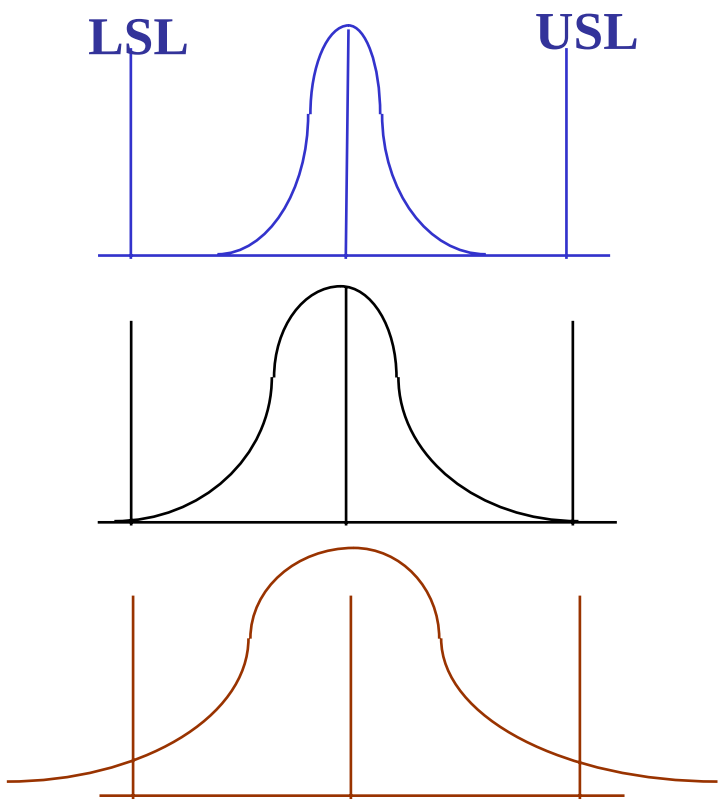
$$C_p = \frac{(UTL - LTL)}{6\sigma}$$

$$C_p = \frac{6\sigma}{6\sigma} = 1$$



Process Capability Index: C_p -- Measure of *Potential* Capability

$$C_p = \frac{\textit{allowable}\ \text{process variation}}{\textit{actual}\ \text{process variation}} = \frac{USL - LSL}{6\sigma}$$

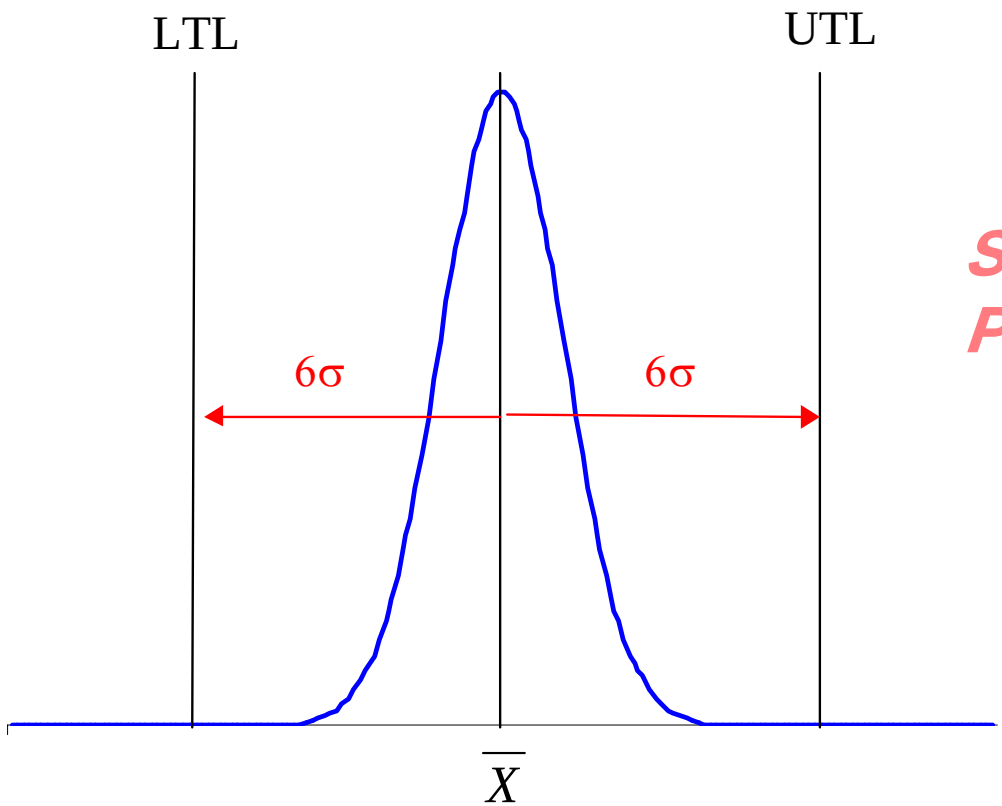


$C_p > 1$

$C_p = 1$

$C_p < 1$

$$C_p = \frac{12\sigma}{6\sigma} = 2$$



SIX SIGMA PROCESS

What value of cp is acceptable

Cp<1.0	*poor process*
Cp=1.0	*so ok*
Cp1.3 - 1.5	*good*
Cp=2	*Excellent, that is 6 sigma*

Process Capability Index
Example

A manufacturing process produces a certain part with a mean diameter of 2 inches and a standard deviation of 0.03 inches. The lower and upper engineering specification limits are 1.90 inches and 2.05 inches.

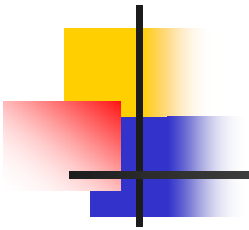
$$C_p = \frac{USL - LSL}{6\sigma} = \frac{2.05 - 1.90}{6(0.03)} = 0.83$$

Process is not a capable process since Cp<1.0

Process Capability Index: C_{pk} -- Measure of *Actual* Capability

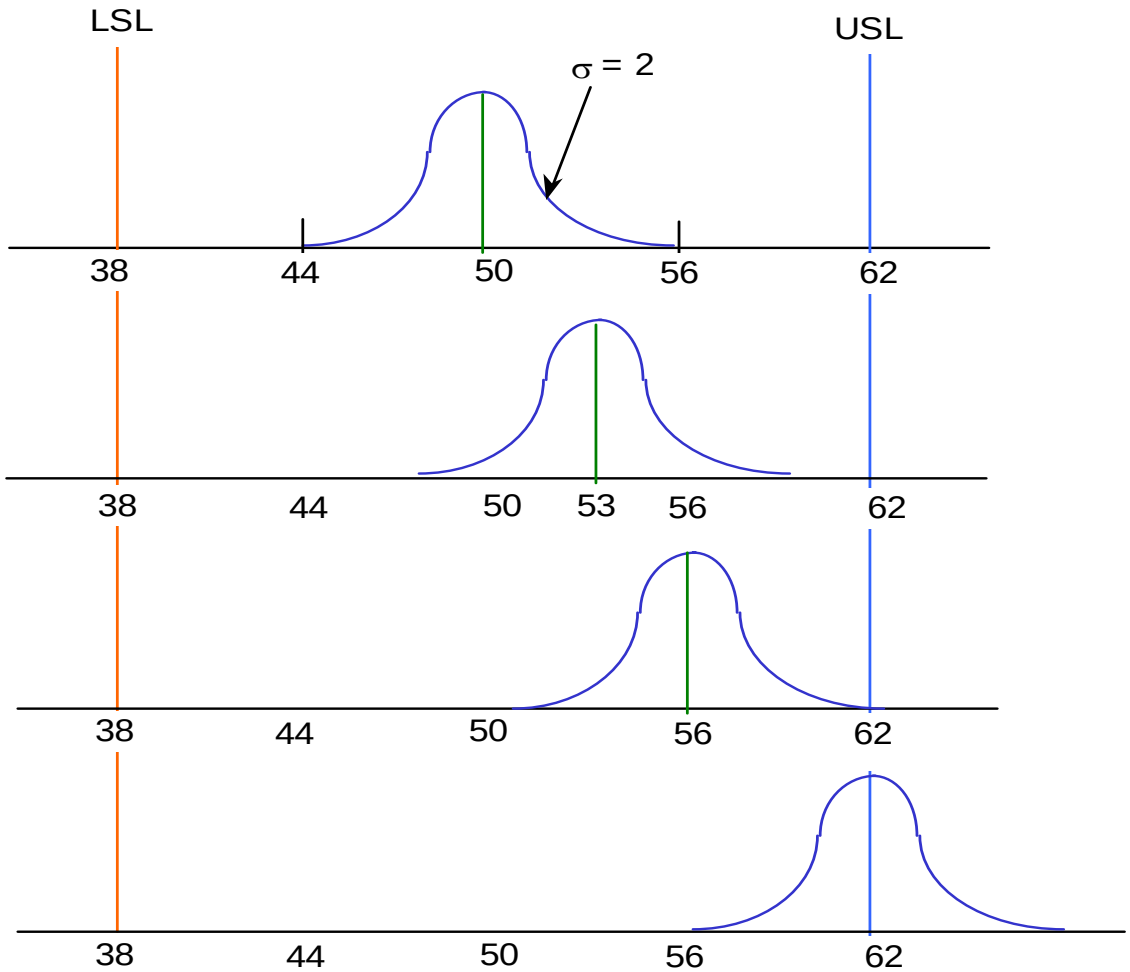
$$C_{pk} = \min\left[\frac{\bar{X} - LSL}{3\sigma}, \frac{USL - \bar{X}}{3\sigma}\right]$$

- σ is the standard deviation of the process



- WHY C_{pk} IS NEEDED?
- IS C_p NOT ENOUGH?

Impact of Process Location on Process Capability

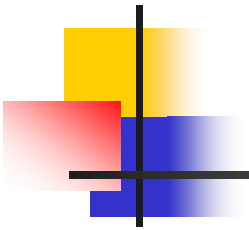


$C_p = 2.0$
$C_{pk} = 2.0$

$C_p = 2.0$
$C_{pk} = 1.5$

$C_p = 2.0$
$C_{pk} = 1.0$

$C_p = 2.0$
$C_{pk} = 0$



WHY Cpk IS NEEDED?

IS Cp NOT ENOUGH?

Cp TELLS U ONLY ABOUT THE SMARTNESS OF CURVE

Cpk TELLS U ABOUT THE POSITIONING / LOCATION OF THE CURVE

Process Capability Index
Example

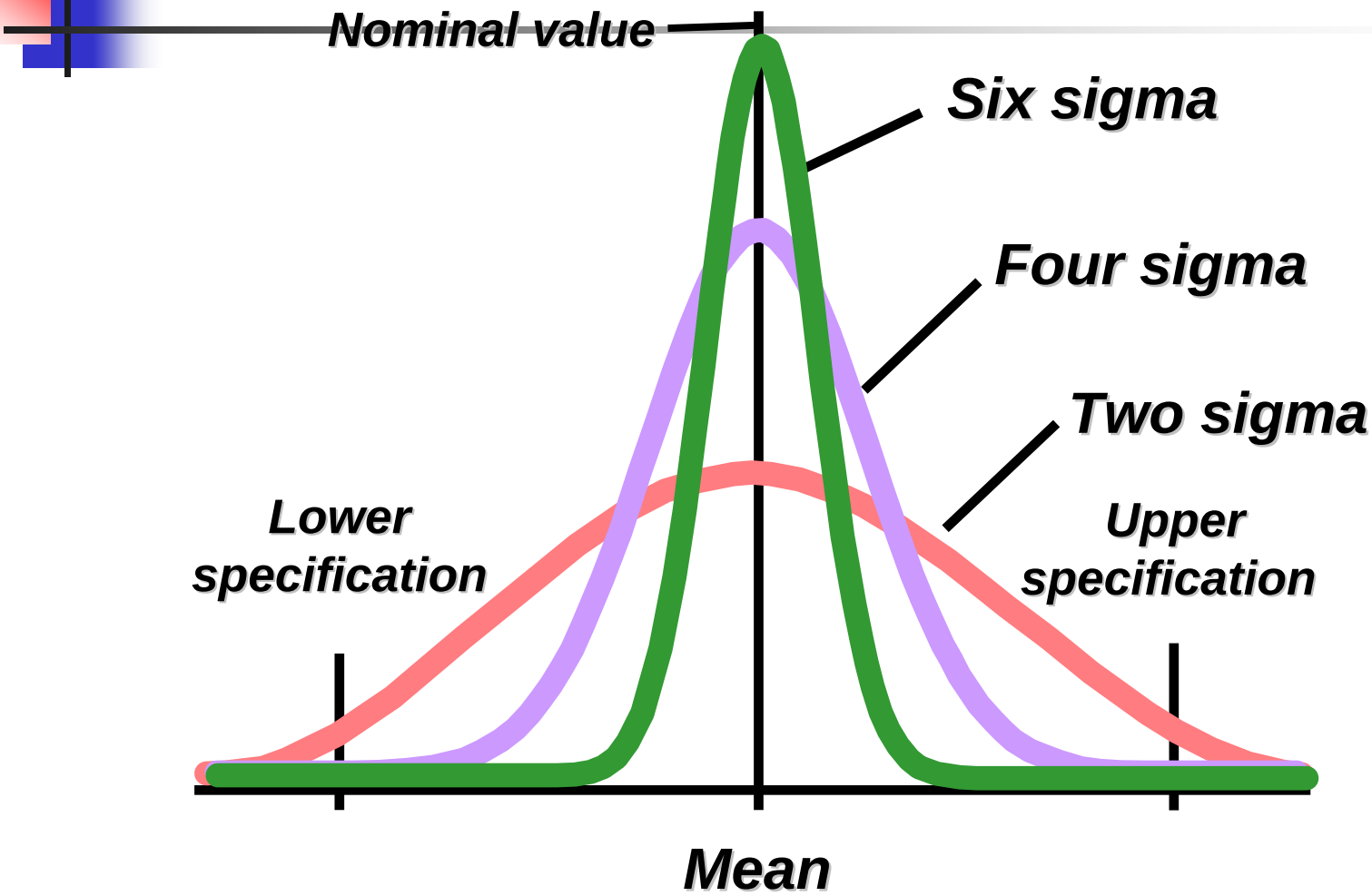
A manufacturing process produces a certain part with a mean diameter of 2 inches and a standard deviation of 0.03 inches. The lower and upper engineering specification limits are 1.90 inches and 2.05 inches.

$$C_{pk} = \min\left[\frac{\bar{X} - LSL}{3\sigma}, \frac{USL - \bar{X}}{3\sigma}\right] = \min\left[\frac{2 - 1.90}{3(0.03)}, \frac{2.05 - 2}{3(0.03)}\right]$$

$$= \min[1.11, 0.56] = 0.56$$

Therefore, the process is not capable (the variation is too large and the process mean is not on target)

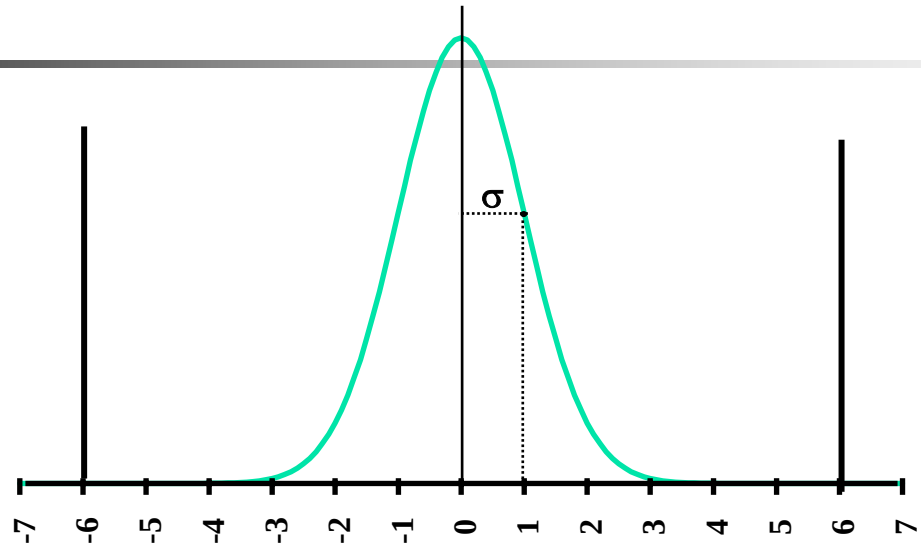
Process Capability



Six Sigma

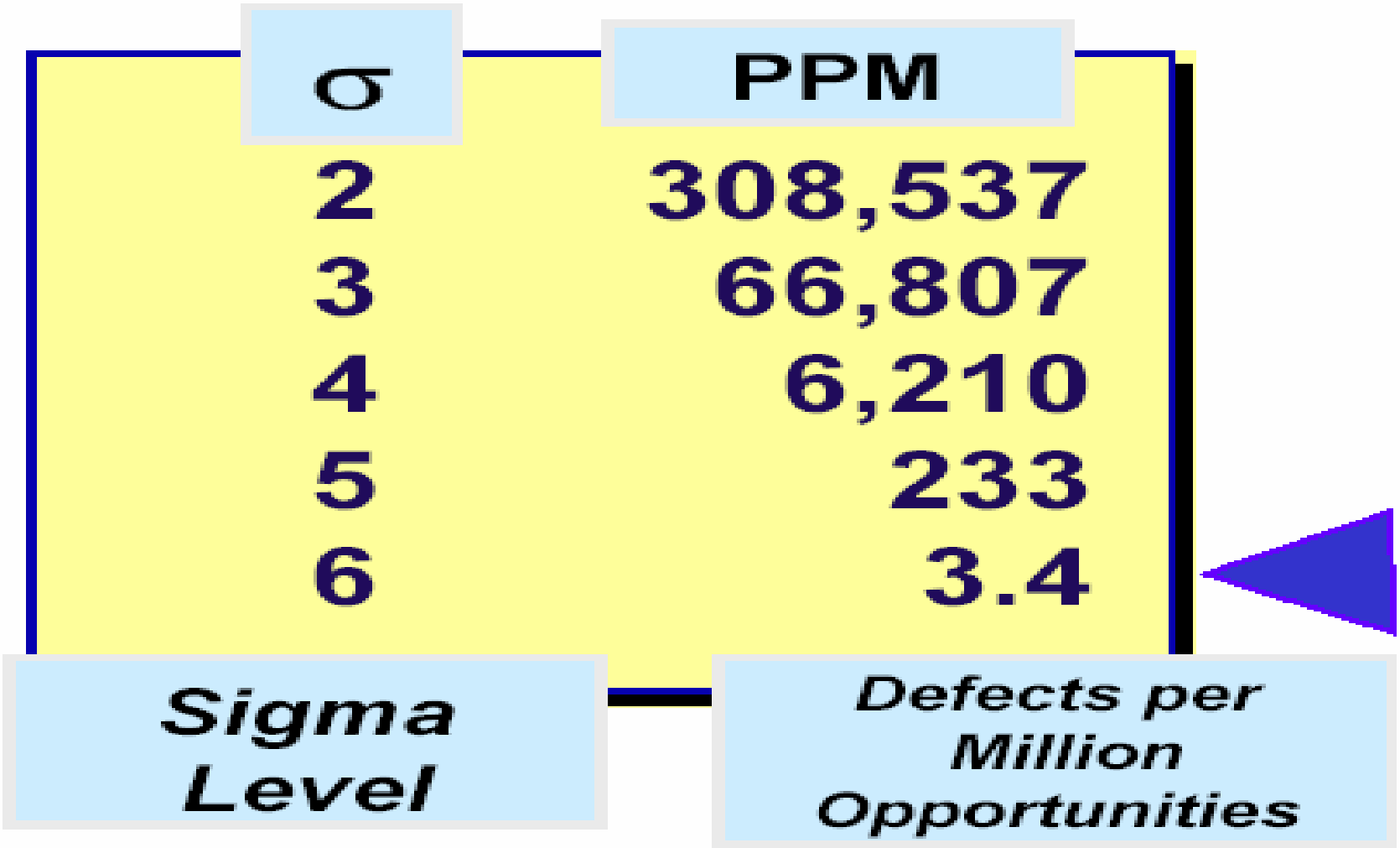
- Is the relentless and rigorous pursuit of the reduction of variation in all critical processes to achieve continuous and breakthrough improvements that impact the bottom line of the organization and increase customer satisfaction.
- It is an organizational initiative designed to create manufacturing, service and administrative processes that produce approximately 3.4 defects per million. Opportunities (DPMO).

WITH OUT ANY DEVIATION



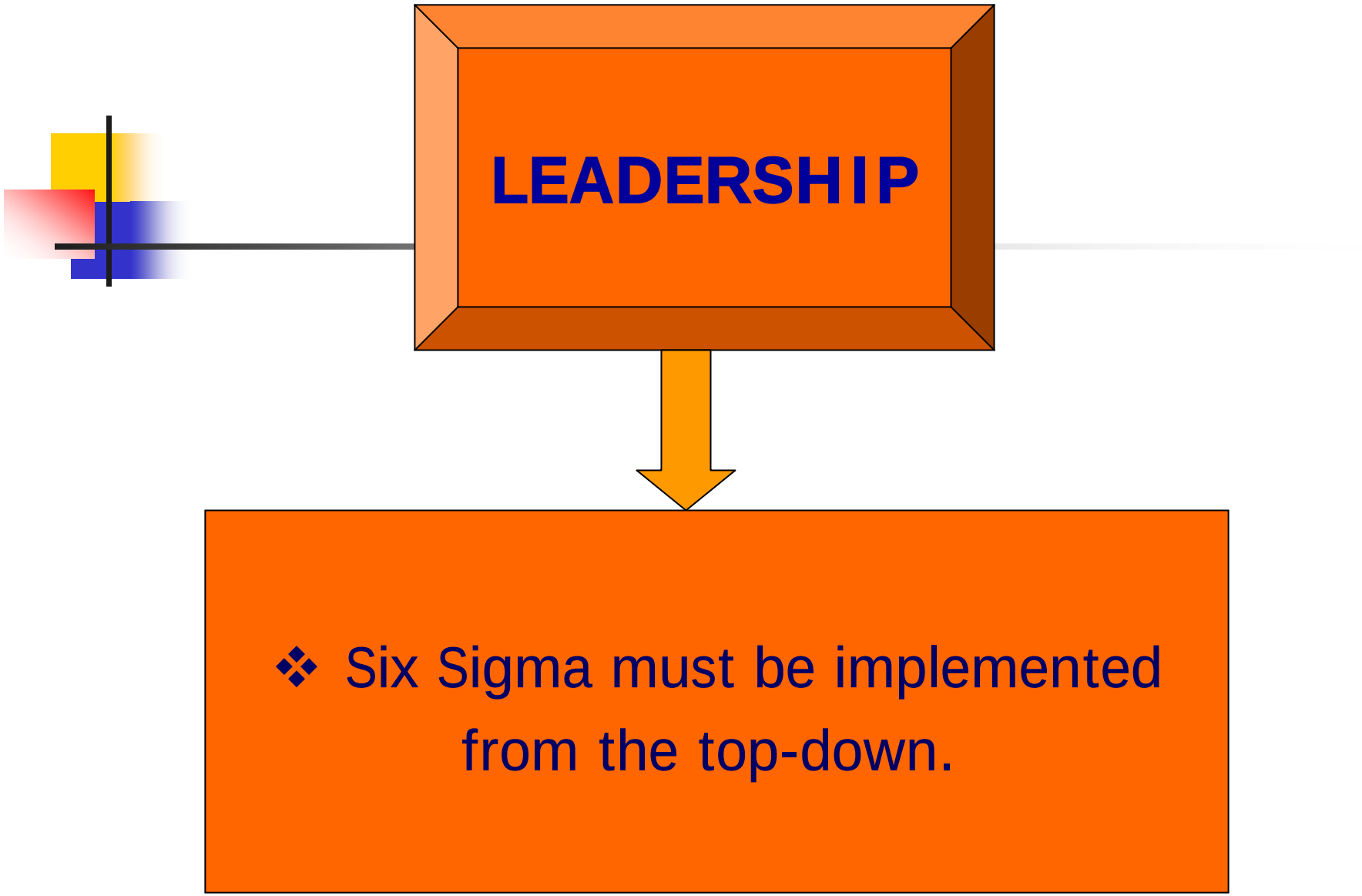
between + / - 1σ	68.27 %	result: 317300 ppm outside (deviation)
between + / - 2σ	95.45 %	45500 ppm
between + / - 3σ	99.73 %	2700 ppm
between + / - 4σ	99.9937 %	63 ppm
between + / - 5σ	99.999943 %	0.57 ppm
between + / - 6σ	99.9999998 %	0.002 ppm

Distribution shifted ± 1.5



DMAIC Model

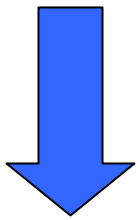
- The model that is used to improve a process in Six Sigma management is called the DMAIC model. This stands for:
  - Define
  - Measure
  - Analyze
  - Improve
  - Control


LEADERSHIP
❖ Six Sigma must be implemented from the top-down.

Green Belt.

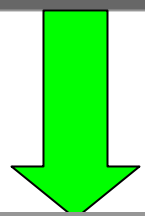
- Green Belts are project leaders who receive two weeks of training on the Six Sigma roadmap and essential elements of Statistical methodologies supporting Six Sigma projects.
- Successful Green Belts are able to allocate 50% of their time to their four to six month Six Sigma Project.

CHAMPIONS

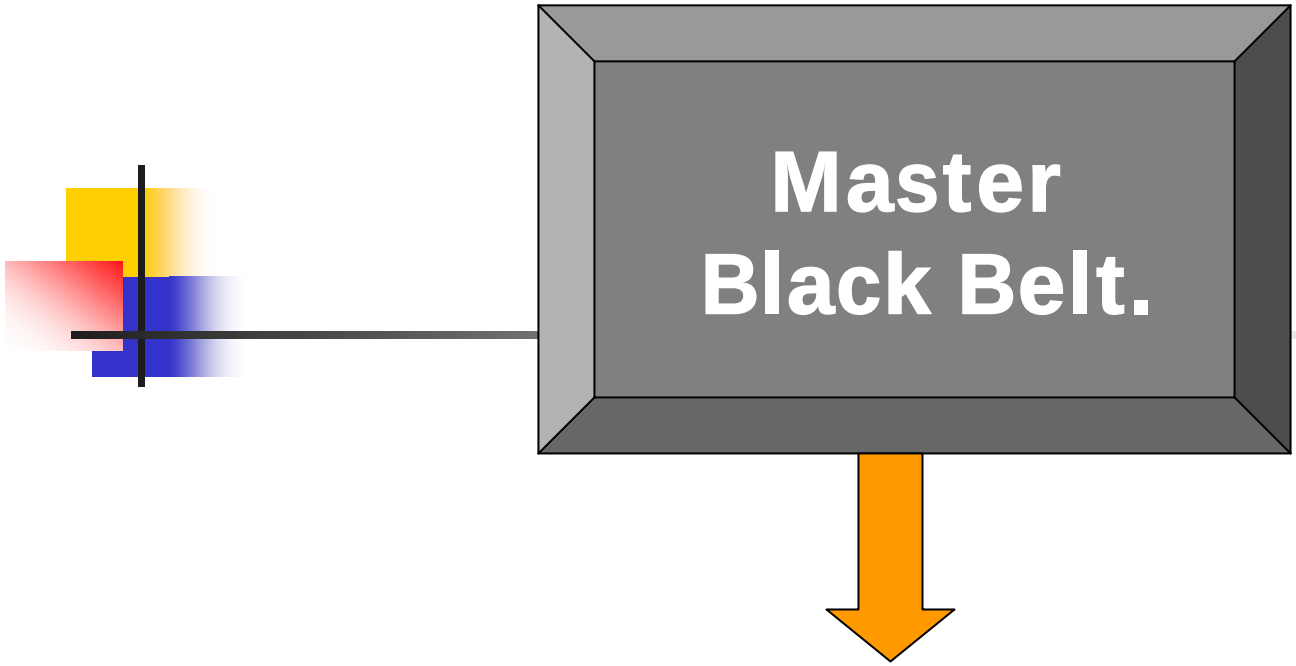


An executive level business leader who facilitates the leadership, implementation, and deployment of Six Sigma philosophies.

Black Belt.

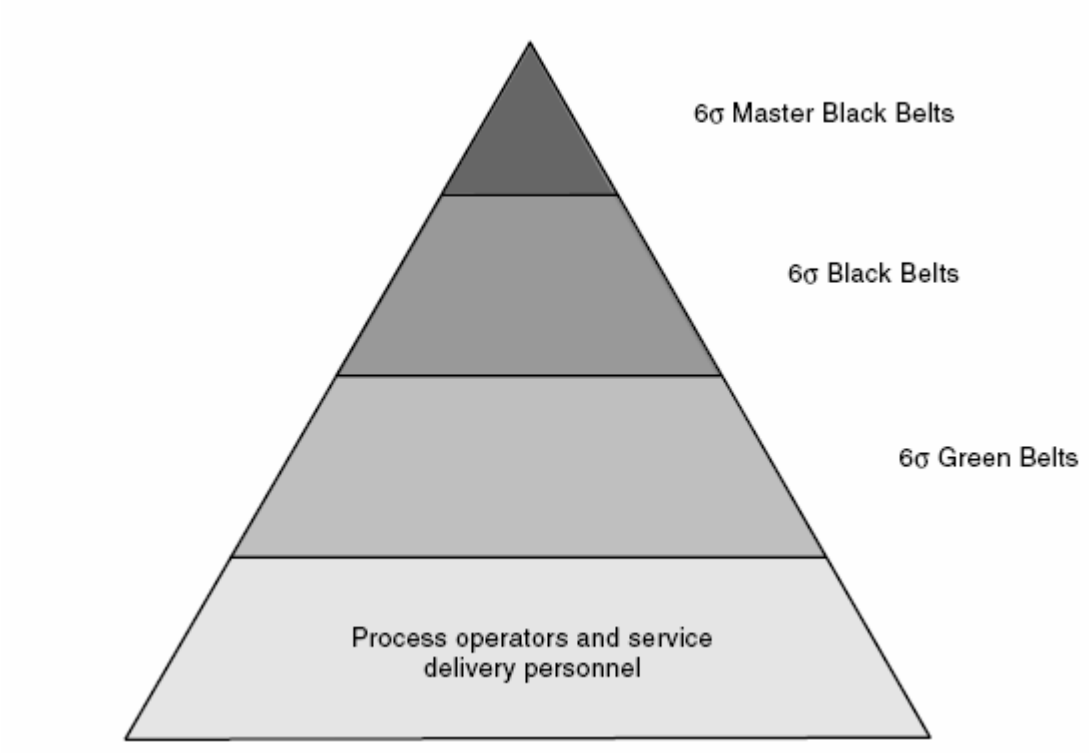


- Black Belts are project leaders who receive four weeks of training focusing on the Six Sigma Road map and extensive statistical methodologies
- Successful Black Belts normally dedicate at least 75% of their time to 4 -6 month Six Sigma Project.



- Master Black Belt provides technical leadership to Six Sigma program.
- The mentor and teacher of the of Six Sigma Black Belt and Six Sigma Green Belt.

6 Sigma Support Personnel

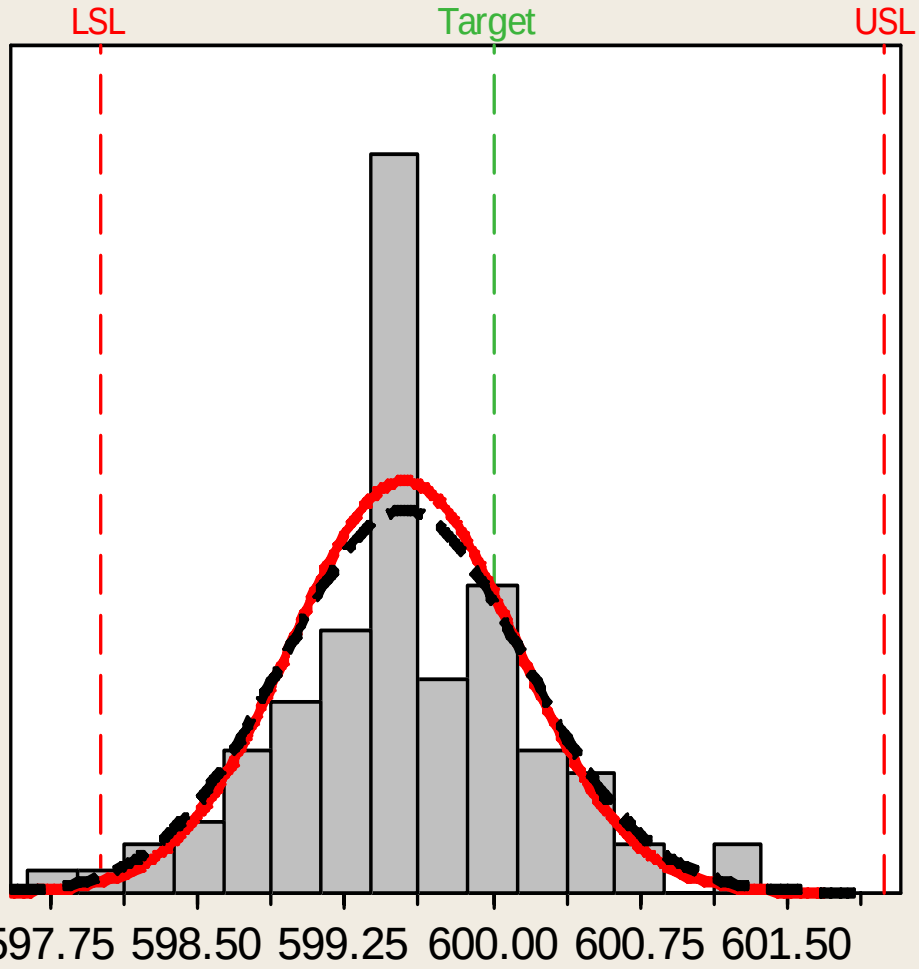


Process capability calculation using Minitab

Please refer to the examples discussed in class

Process Capability of Supp1

Process Data	
LSL	598
Target	600
USL	602
Sample Mean	599.548
Sample N	100
StDev(Within)	0.576429
StDev(Overall)	0.620865



Within
Overall

Potential (Within) Capability	
Cp	1.16
CPL	0.90
CPU	1.42
Cpk	0.90

Overall Capability	
Pp	1.07
PPL	0.83
PPU	1.32
Ppk	0.83
Cpm	0.87

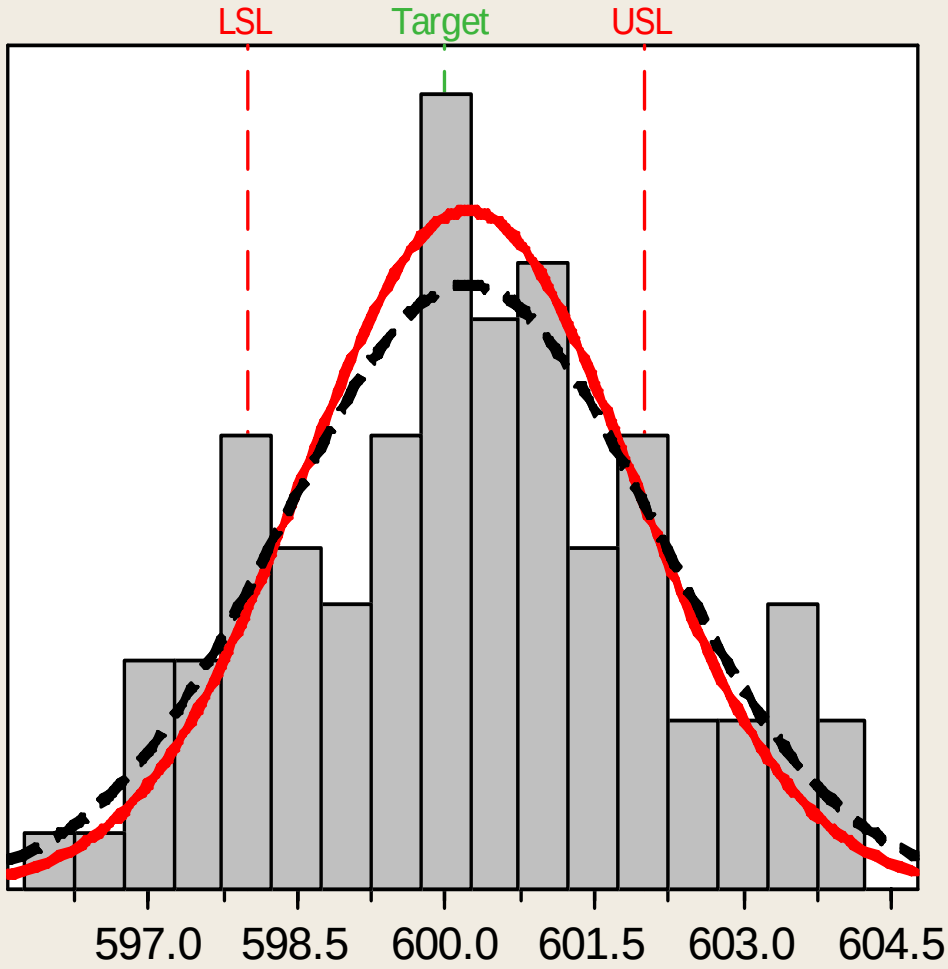
Observed Performance	
PPM < LSL	10000.00
PPM > USL	0.00
PPM Total	10000.00

Exp. Within Performance	
PPM < LSL	3621.06
PPM > USL	10.51
PPM Total	3631.57

Exp. Overall Performance	
PPM < LSL	6328.16
PPM > USL	39.19
PPM Total	6367.35

Process Capability of Supp2

Process Data	
LSL	598
Target	600
USL	602
Sample Mean	600.23
Sample N	100
StDev(Within)	1.67231
StDev(Overall)	1.87861



Within
Overall

Potential (Within) Capability	
Cp	0.40
CPL	0.44
CPU	0.35
Cpk	0.35

Overall Capability	
Pp	0.35
PPL	0.40
PPU	0.31
Ppk	0.31
Cpm	0.35

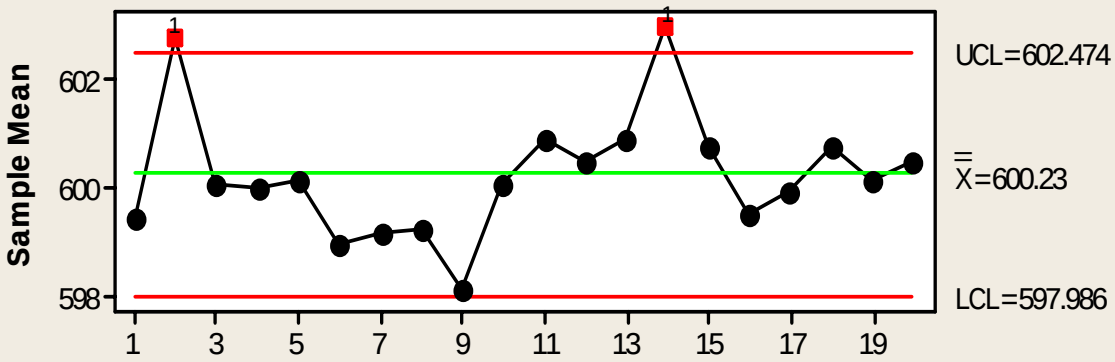
Observed Performance	
PPM < LSL	110000.00
PPM > USL	180000.00
PPM Total	290000.00

Exp. Within Performance	
PPM < LSL	91186.50
PPM > USL	144933.01
PPM Total	236119.51

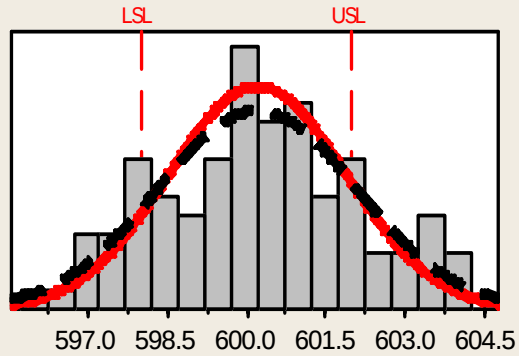
Exp. Overall Performance	
PPM < LSL	117604.95
PPM > USL	173049.32
PPM Total	290654.27

Process Capability Sixpack of Supplier 2

Xbar Chart

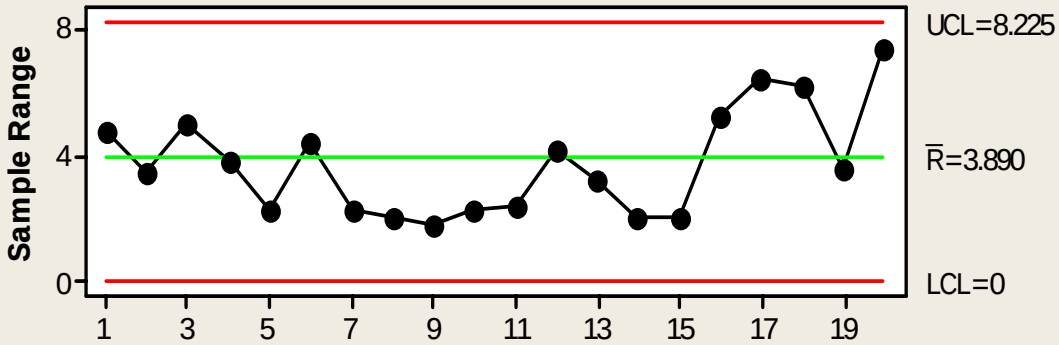


Capability Histogram



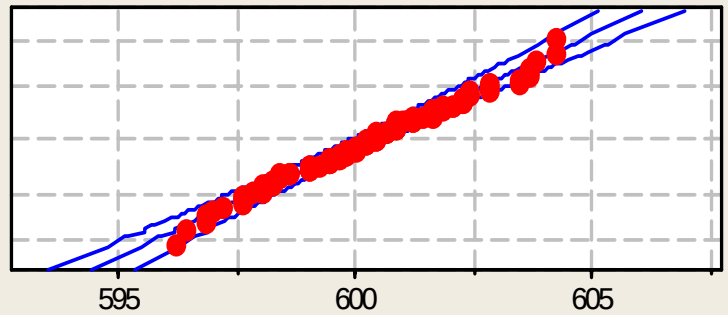
Specifications	
LSL	598
USL	602

R Chart

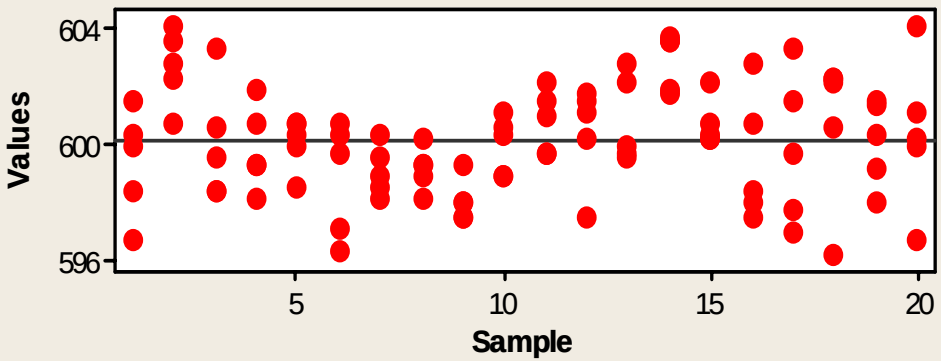


Normal Prob Plot

AD: 0.287, P: 0.615

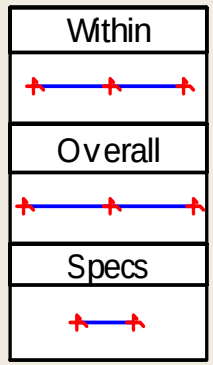


Last 20 Subgroups



Capability Plot

Within	
StDev	1.67231
Cp	0.4
Cpk	0.35



Overall	
StDev	1.87861
Pp	0.35
Ppk	0.31
Cpm	*