Data Champion module

Lean Six Sigma Master Black Belt

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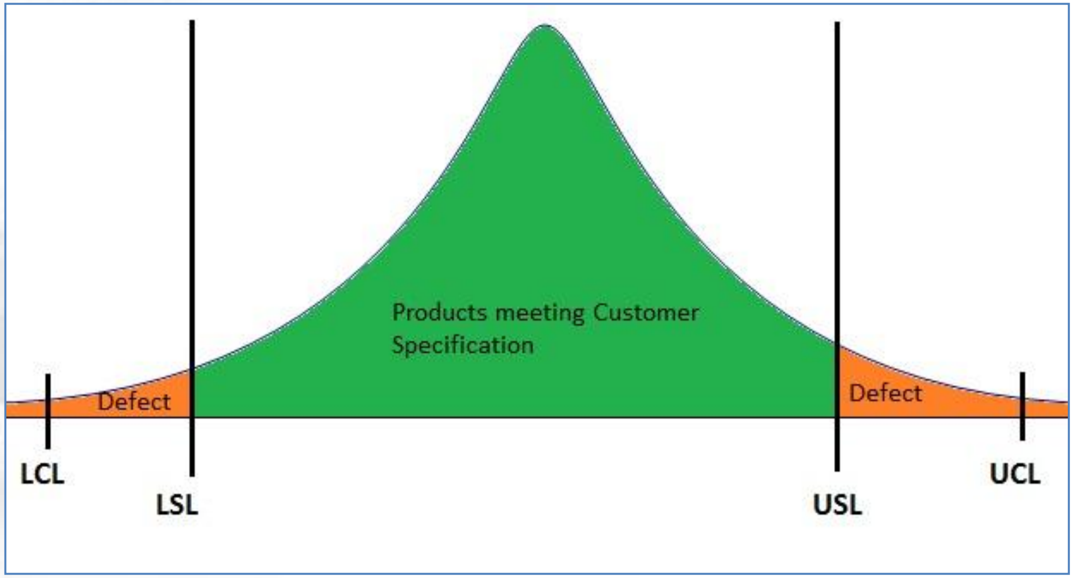
What is Quality?

- The limits on the product's quality characteristics are called the product's specification limits, or "specs."
- Some quality authorities define quality as producing units of a product that fall anywhere within the product's spec limits.
  - These units are called conforming (to specs) or non-defective units.
  - Units that fall outside the specs limits are called nonconforming or defective units.



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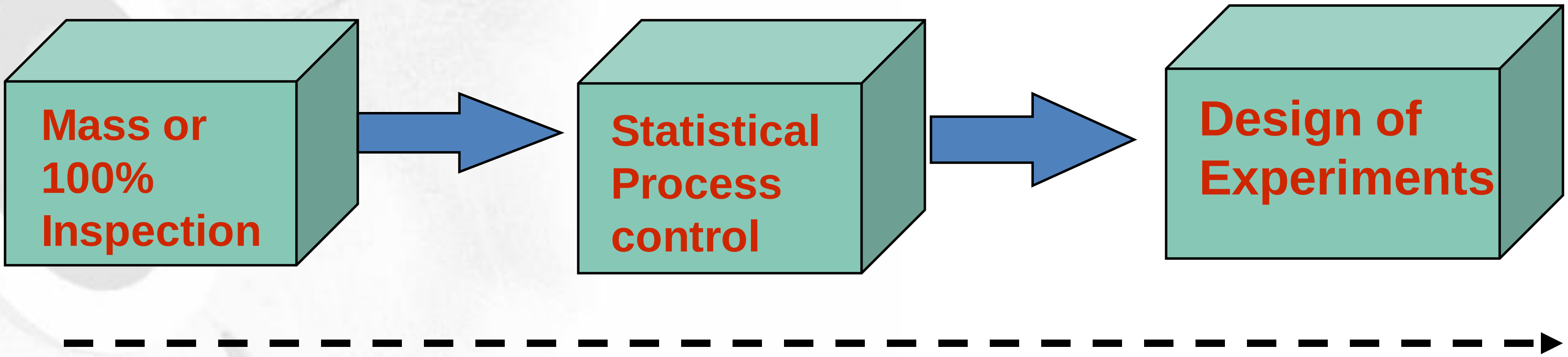
Evolution of Defect Prevention

Prevent defects from being shipped

Prevent defects from being produced

Prevent defects before production

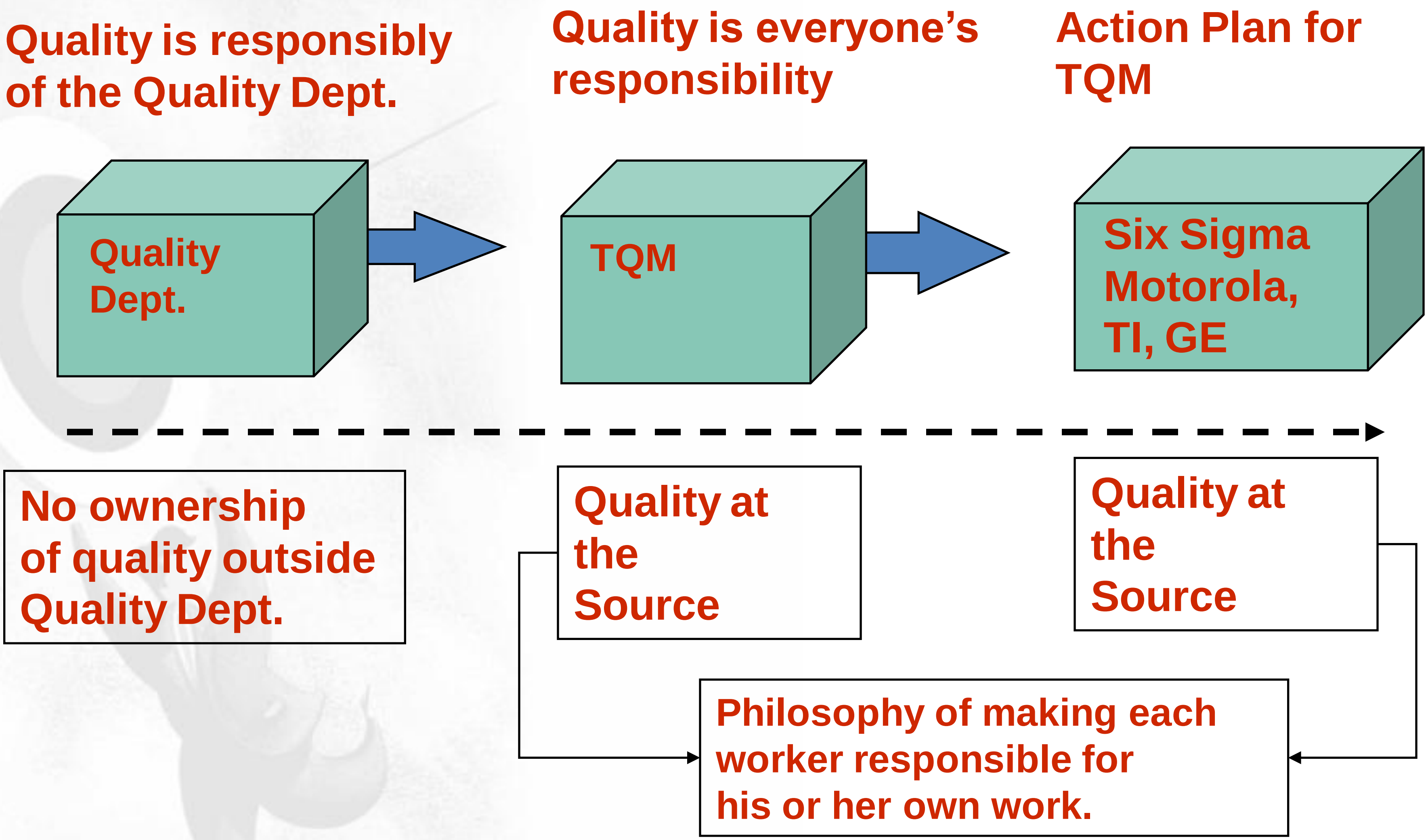


Reactive-
Fix the Product

Proactive-
Fix the process

Proactive-
Design quality into product

Evolution of Quality Organizations



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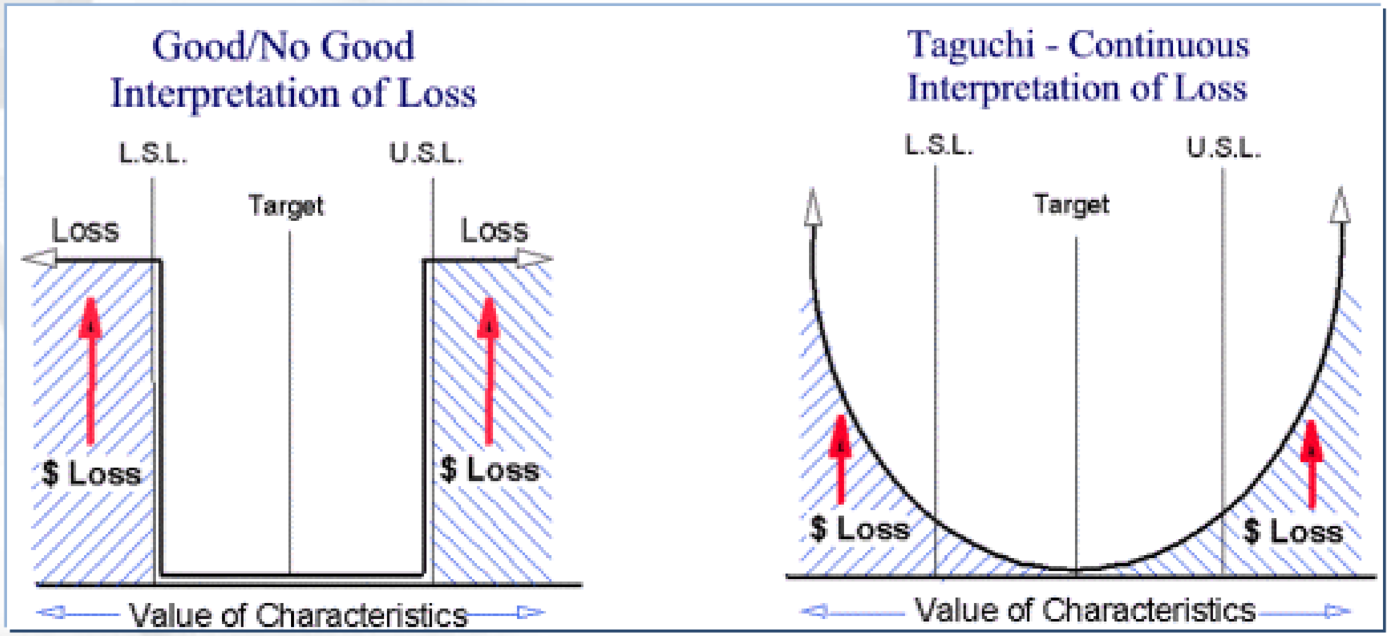
Taguchi's Loss Function

- Taguchi defines Quality Level of a product as the Total Loss incurred by society due to failure of a product to perform as desired when it deviates from the delivered target performance levels.
- This includes costs associated with poor performance, operating costs (which changes as a product ages) and any added expenses due to harmful side effects of the product in use



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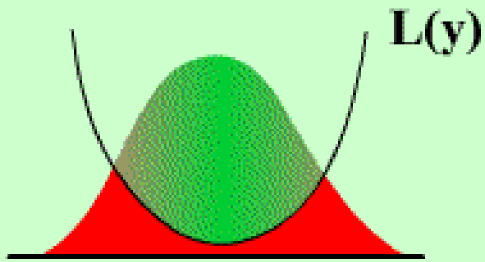
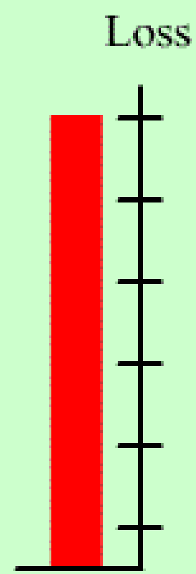
Taguchi Loss Function illustrated

TAGUCHI LOSS FUNCTION

$$L(y) = k(y-m)^2$$

The loss due to performance variation is proportonial to the square of the deviation of the performance characteristic from its nominal value.





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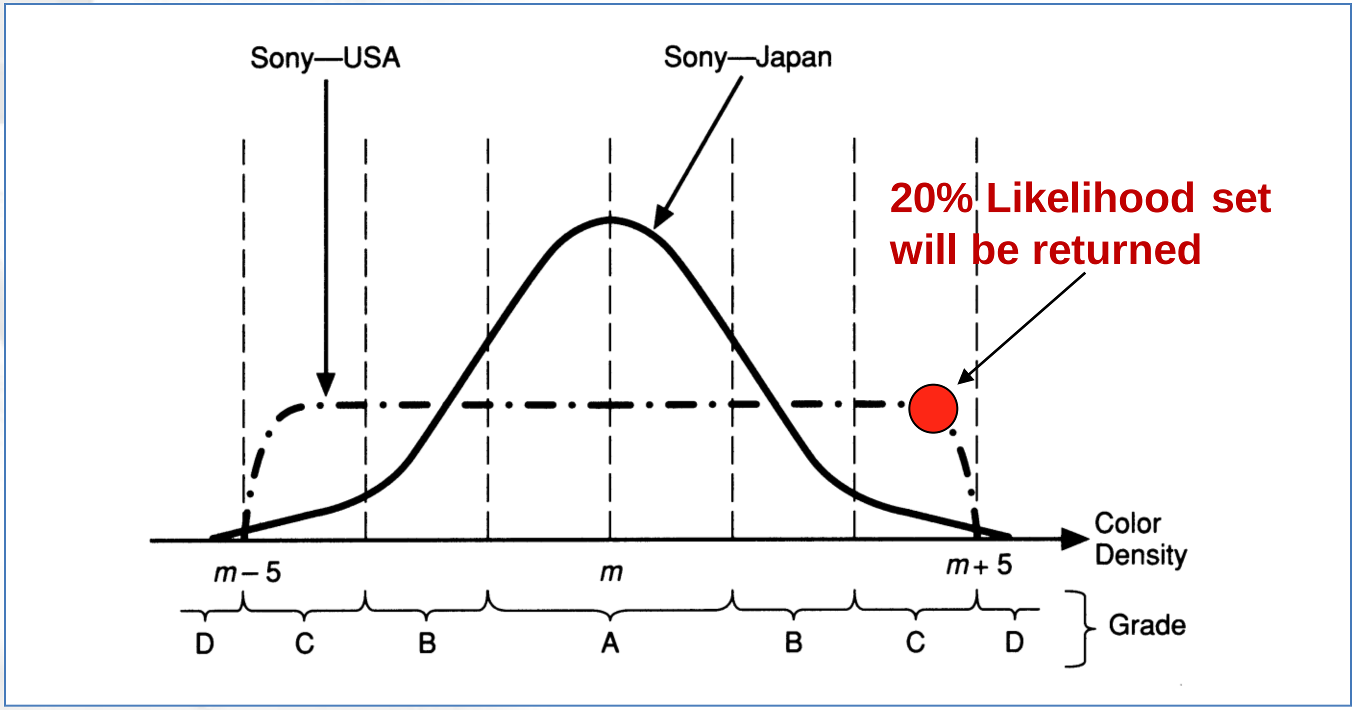
Study of Sony USA and Sony Japan

Distribution of color density in Television sets

- Sony USA is producing more lower grade TVs. This is on account of focusing on meeting color density specifications (internal view).
- While lower grade televisions can be sold in the market, the chances of return/losses increase the further away we go from the target value.



Operate on Target

- Being on target is more important than being within the spec limits.
- Target value is the value of the quality characteristic, X, of a product or service that maximizes customer satisfaction.
- Any deviation from the target value imposes an economic loss on the customer, even if all product is within spec!

Variability	On Target	Off-Target
High	Haphazardly on target	Haphazardly off target
Low	Consistently on target	Consistently off target

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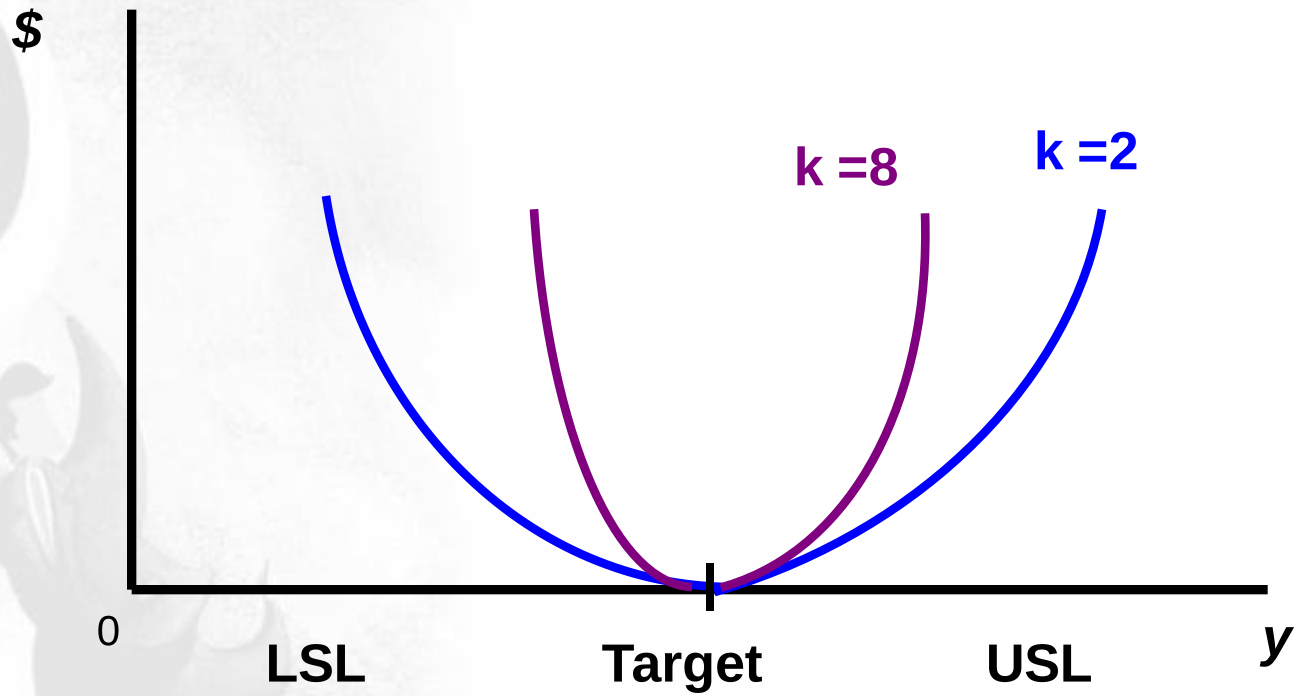
Loss Function – Process on Target

$$L(y) = k(y-m)^2, \text{ where } k = \text{a constant}$$



Considering the Cost of Loss

- k in the L(y) equation is found from:

$$k = A_0 / \Delta_0^2$$

A_0 is cost of repair or replace a product and must include loss due to unavailability during repair

Δ_0 is the functional limit on y of a product where it would fail to perform its function half the time

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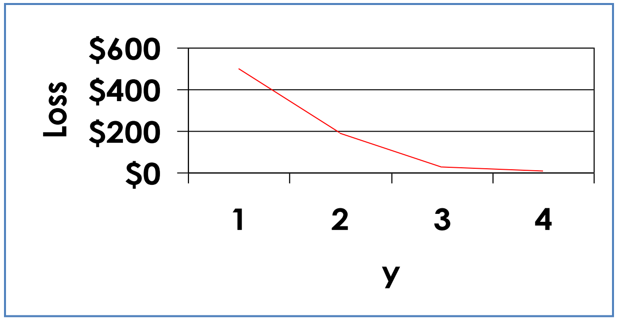
Three types of Loss Functions

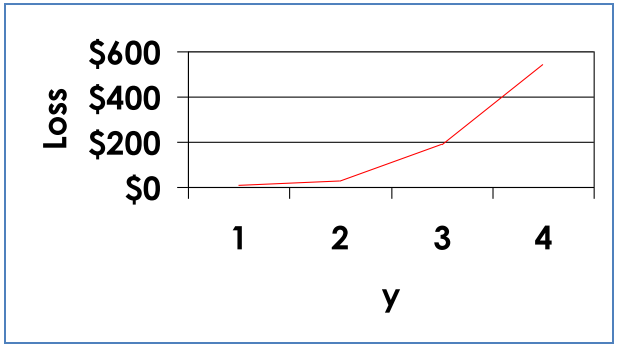
1. Larger the Better (LTB):

$$L(y) = k\left[\frac{1}{y^2} \right]$$



2. Smaller the Better (STB):

$$L(y) = ky^2$$

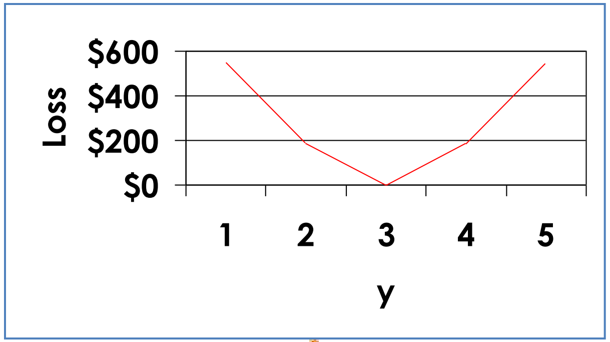


3. Nominal the Best (NTB):

$$L(y) = k(y - m)^2$$

where:

m is the target of the process specification



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Loss Functions

Type	Loss Function per unit	Average Loss Function
Nominal-the-Best (NTB)	$L(y) = \frac{A_0}{\Delta^2}(y-m)^2$	$\overline{L(y)} = \frac{A_0}{\Delta^2}[S^2 + (\bar{y}-m)^2]$
Smaller-the-Better (STB)	$L(y) = \frac{A_0}{\Delta^2}(y)^2$	$\overline{L(y)} = \frac{A_0}{\Delta^2}[S^2 + (\bar{y})^2]$
Larger-the-Better (LTB)	$L(y) = A_0\Delta^2(\frac{1}{y})^2$	$\overline{L(y)} = A_0\Delta^2[\frac{1}{n}\sum_{i=1}^{n}(\frac{1}{y_i})^2]$

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Nominal-the-Best Loss Function Example

- We can define a processes average loss as:

$$\bar{L} = k\left[s^2 + \left(\bar{y} - m\right)^2 \right]$$

- s is process (product) Standard Deviation
- y_{bar} is process (product) mean

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Example cont.

- Process specification is: 8.5±.05 units
- Historically: y_{bar} = 8.492 and s = 0.016
- A_0 is $2 (a very low number of this type!) found by estimating that the loss is 10% of the $20 product cost when a part is exactly 8.55 or 8.45 units

- Average Loss per unit:

$$\overline{L} = \left(2 / .05^2 \right) \left[(0.016)^2 + (8.492 - 8.500)^2 \right]$$

$$\overline{L} = 800 * .00032 = \$0.256$$

- If we make 250,000 units a year
- Annual Loss is $64,000

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Example continued: Fixing it!

1. Shift the Mean to nominal

$$\overline{L} = 800\left[.016^2 + (0)^2\right] = \$0.2048$$

Annual Loss is $51200 about 20% reduction

2. Reduce variation (s = 0.01)

$$\overline{L} = 800\left[.010^2 + (.008)^2\right] = \$0.1312$$

Annual Loss is $32800 about 50% reduction

3. Fix Both!

$$\overline{L} = 800\left[.010^2 + (0)^2\right] = \$0.08$$

Annual Loss is $20000 about 66% reduction

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How to use Loss Function

1. The loss function can be used to quantify a design's quality
2. The loss function can be used to compare the expected cost of quality relative to the manufacturing cost
3. The loss function can be used to determine tolerances

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Limitations of Loss Function

1. The loss function looks back at an existing design's performance
2. It does not necessarily predict the ultimate performance of a system
   - This is because the loss function is not independent of adjustment of the mean after reducing variability
   - That is, if a system is stable in the presence of noise but not on target, then the quality loss is high
   - However, a simple adjustment might put such a system on target, resulting in very low quality loss.

- Thus the loss function is not a suitable metric for parameter design optimization where it is useful to reduce variability ***independent*** of putting the system on target.

- We will see later that Signal-to-noise metric is designed to optimize the robustness of a product or process.

Thank You