Lecture # 26

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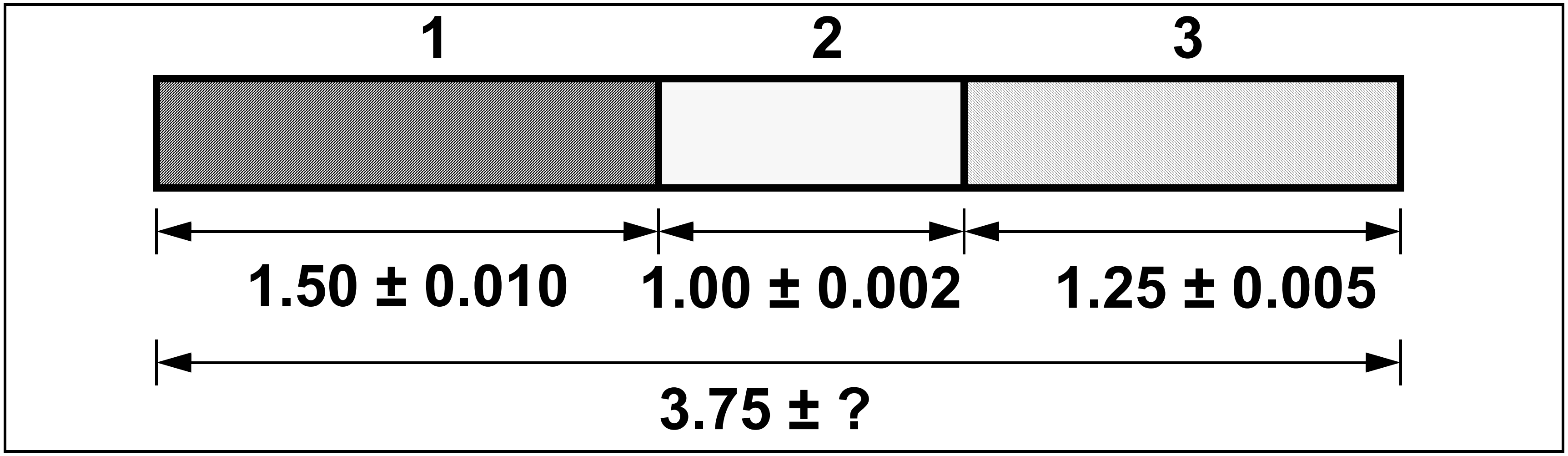
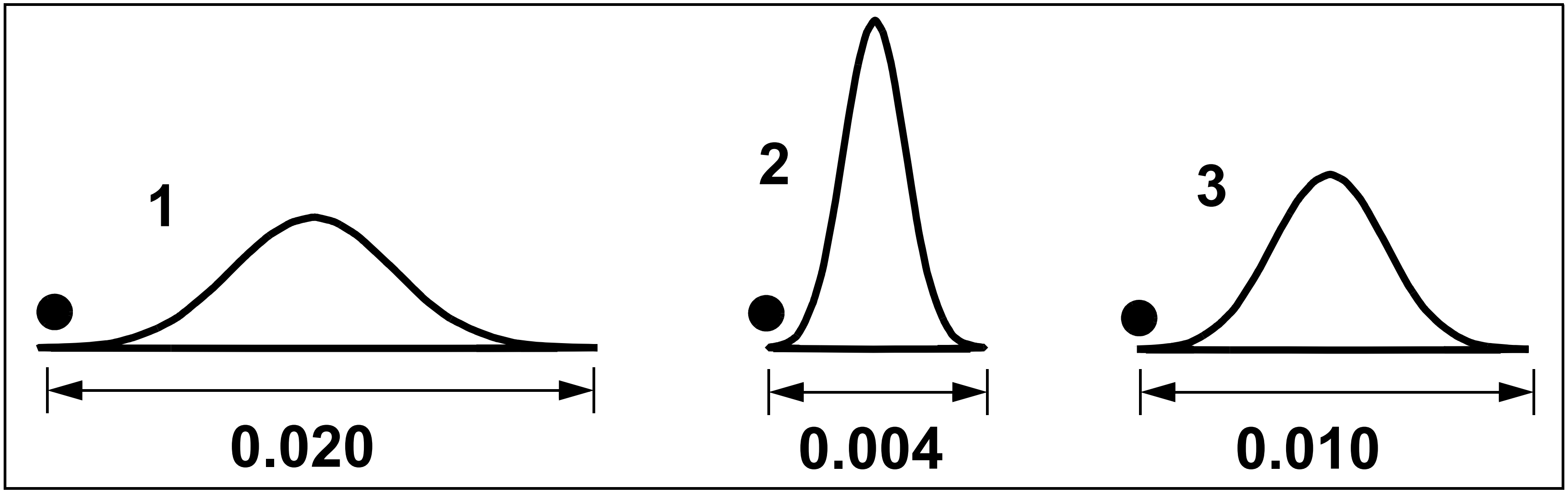
Assembly Tolerances



We might naively set the assembly tolerance by simply adding tolerances: ± 0.017

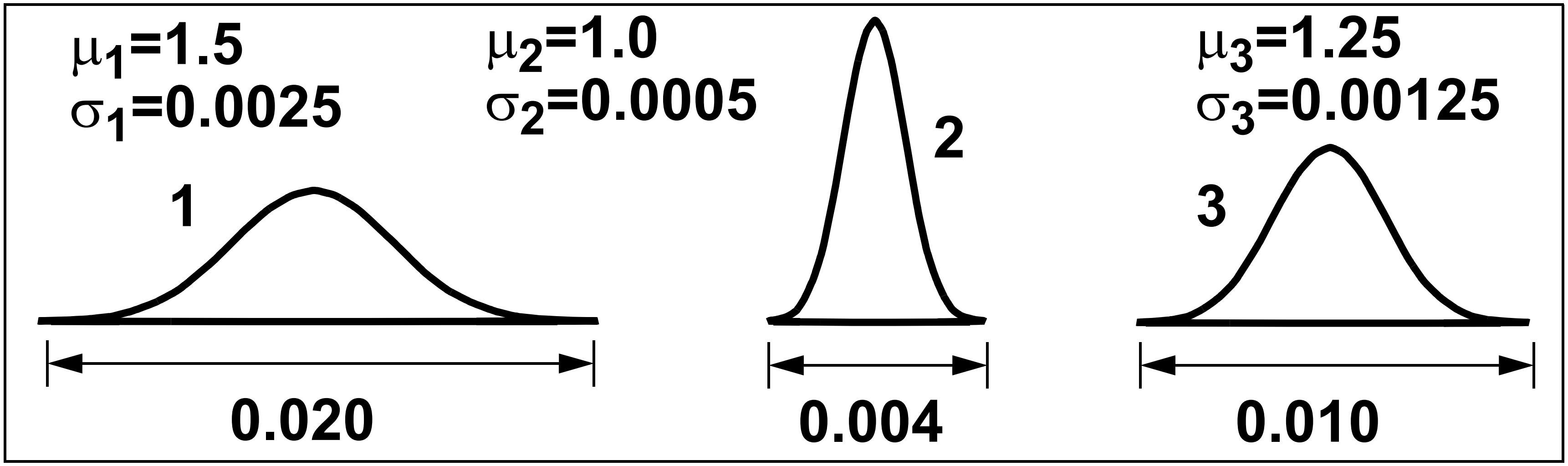
Concerned that parts 1, 2, & 3 might be selected right at the tolerances - want assembly to be ok

Individuals & Assemblies



Let's assume specs are ±4σ from the mean/nominal
Probability of a point at or below -4σ = 0.00003
Probability of simultaneously obtaining 3 such points: $(0.00003)^3$ = 2.7 E-14 (1 in 37 trillion!!)

Describing the Assembly



$$X_A = X_1 + X_2 + X_3$$

$$\mu_A = \mu_1 + \mu_2 + \mu_3 = 3.75$$

$$\sigma_A^2 = \sigma_1^2 + \sigma_2^2 + \sigma_3^2 = 8.0625 \times 10^{-6} \qquad \sigma_A = 0.00284$$

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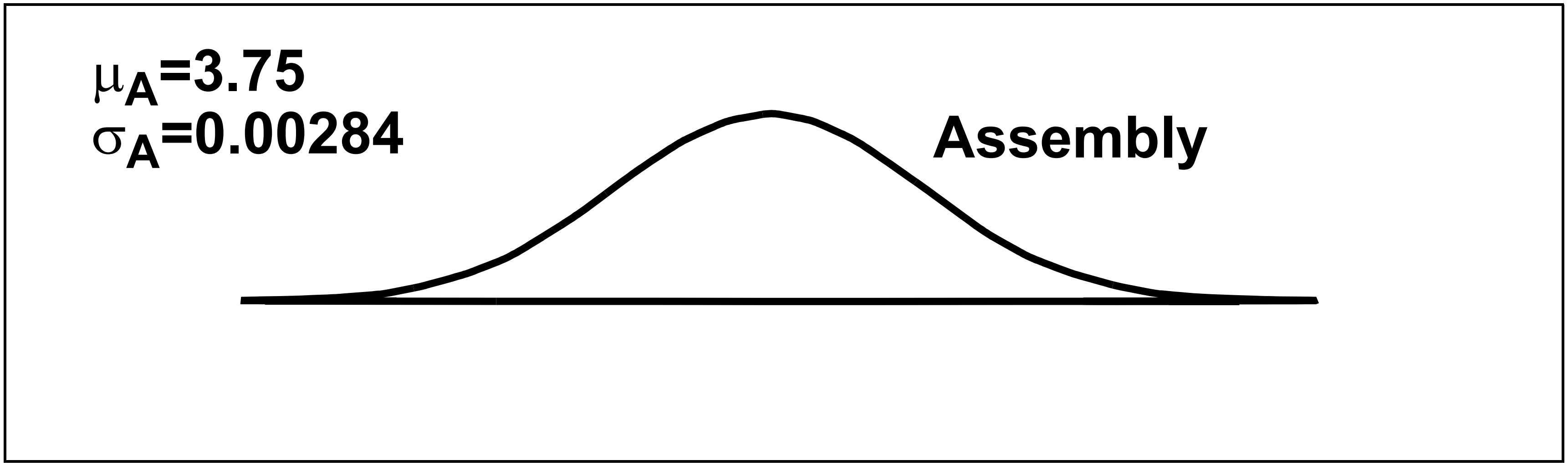
Assembly Distribution



If we again assume that the specs are $\pm 4\sigma_A$ from the mean/nominal, then the tolerance is ± 0.01136

This differs significantly from that obtained by adding!!!

Forces at Work

- **Random assembly**
- **Statistical (so far normal) distribution of part dimensions**
- **Additive Law of Variances**

- **In our example we also assumed that the process was centered at the nominal value.**
- **Tolerances at ±4σ**

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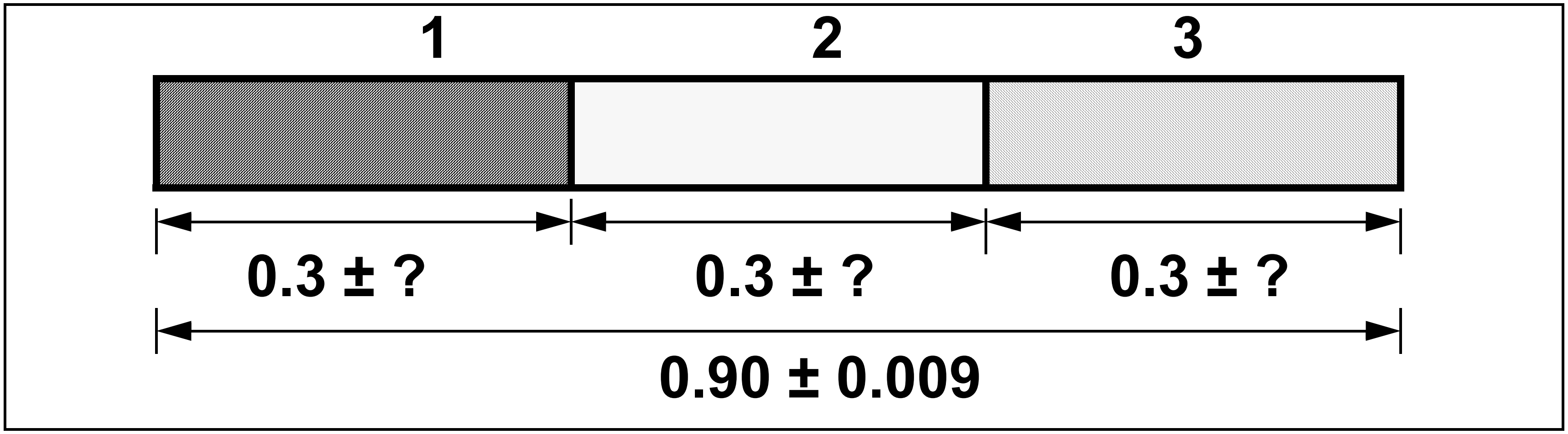
Assembly Example



How do we obtain the tolerances on the individual parts? Divide 0.009 by 3 = 0.003 ??

Let's use the relations that we have developed to obtain the unknown tolerance. Assume 1=2=3

Remember that $X_A = X_1 + X_2 + X_3$

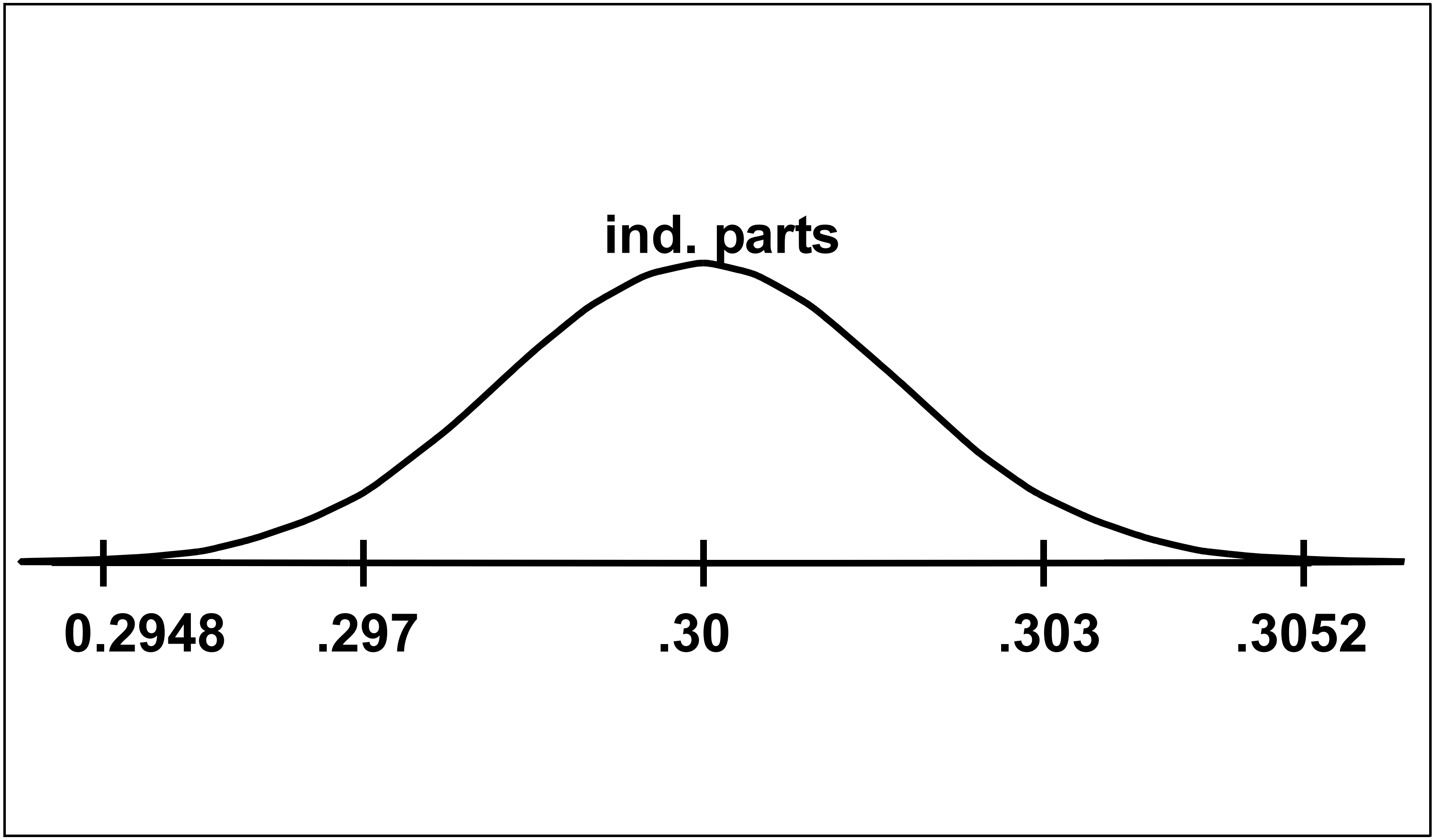
Mean of individual distributions at 0.30

Assembly has tolerance of ± 0.009

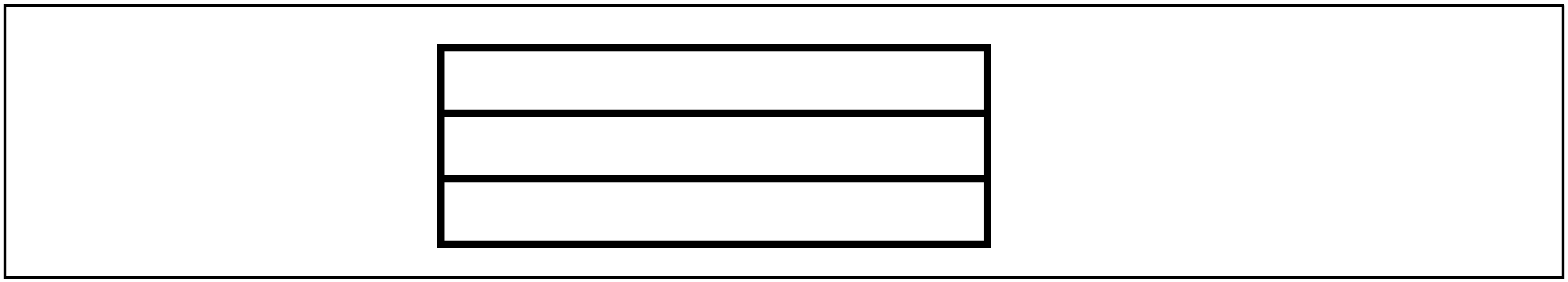
If tolerances are at $\pm 4\sigma_A$, then σ_A = ??

Since $\sigma_A = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2} = \sqrt{3\sigma_p^2}$, σ_p = ??

If we again put the specs for the individual parts at $\pm 4\sigma_p$, this turns out to be ± 0.0052


ind. parts
0.2948
.297
.30
.303
.3052

Effect of Process Centering



Assembly: 0.390 ± 0.050 inch (0.34 -- 0.44)

If tolerances are at $\pm 3\sigma_A$, $\sigma_A = 0.017$

Since $\sigma_A = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2} = \sqrt{3\sigma_p^2}$, $\sigma_p = 0.010$

So, for individ. parts: 0.130 ± 0.030 inch

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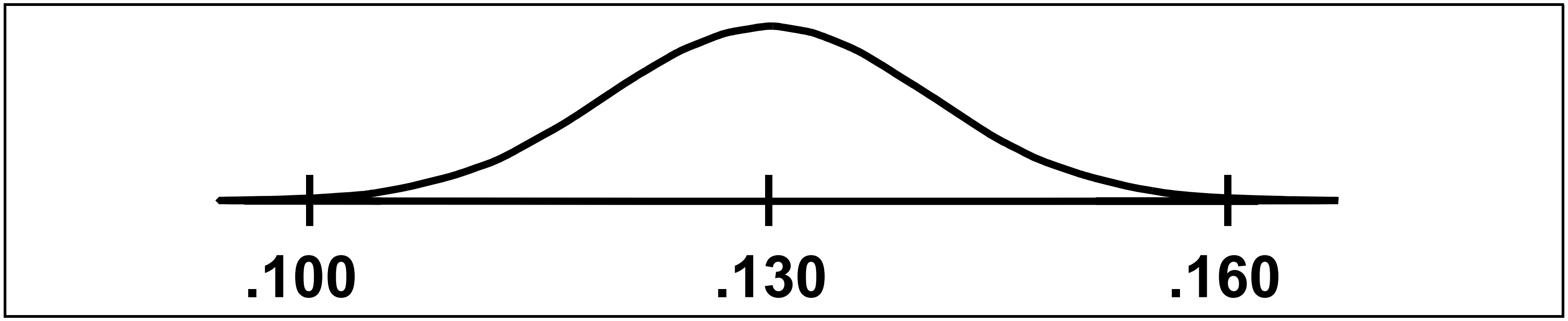
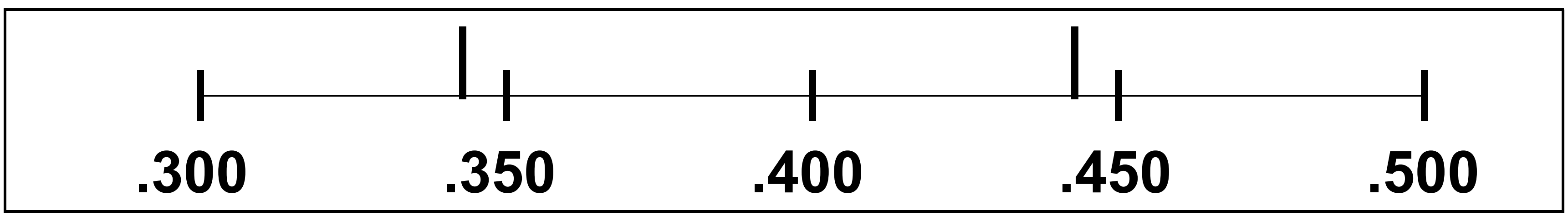
What if we reduce σ_p from 0.010 to 0.005??



$\mu_A =$

$\sigma_A =$



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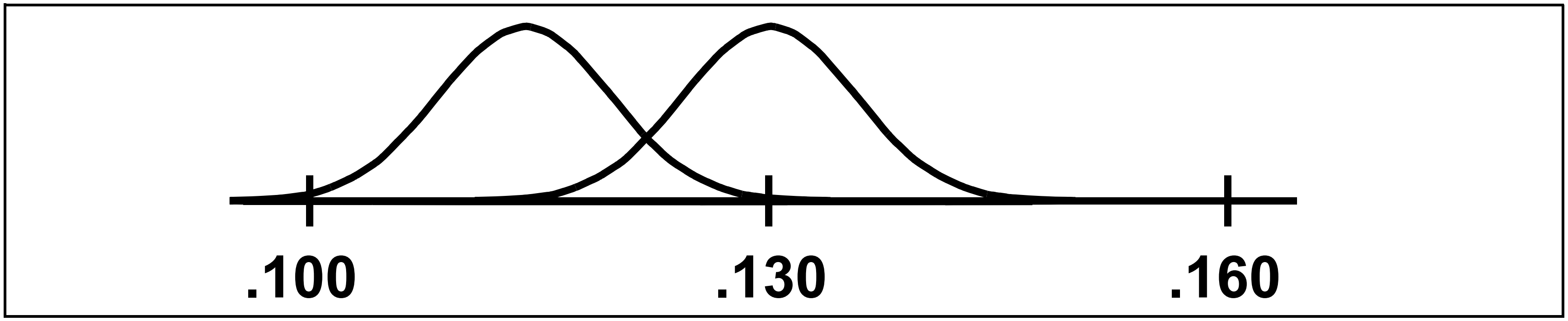
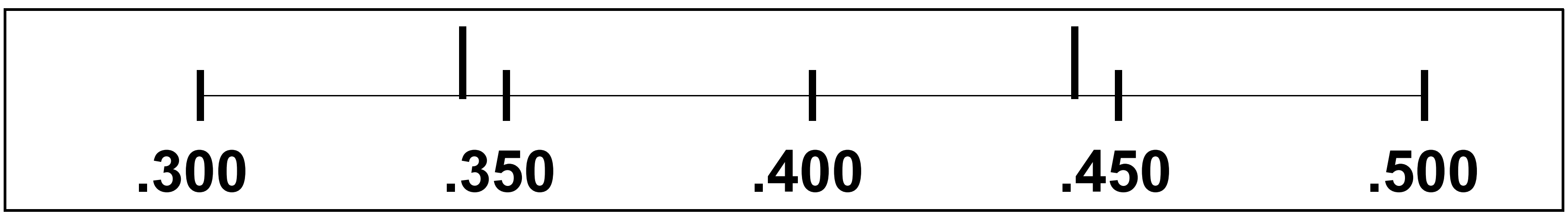
What if we shift process mean to 0.115??

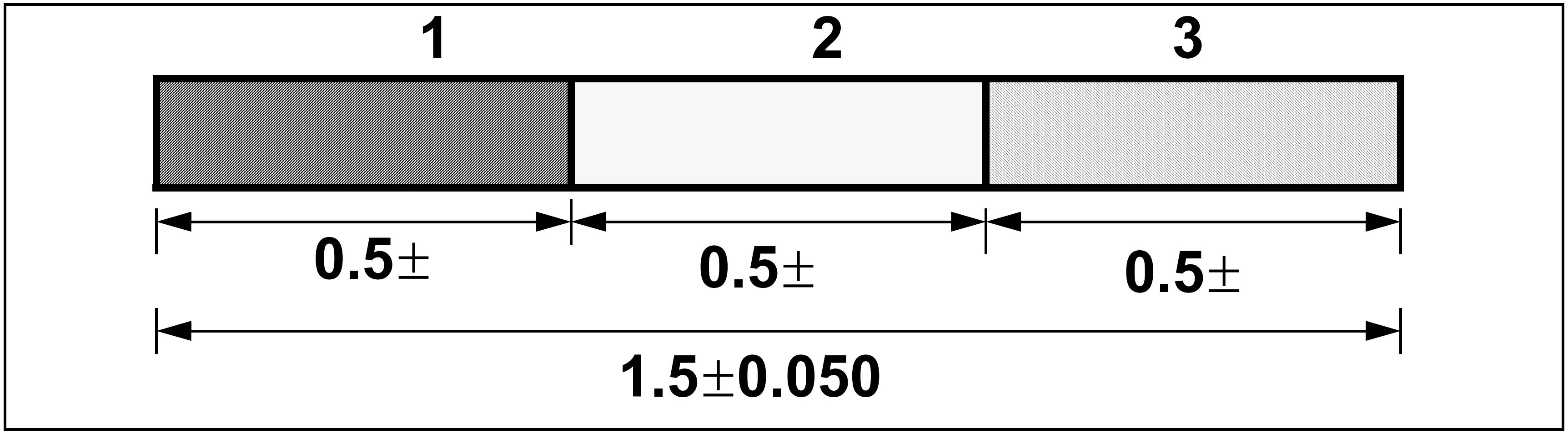


$\mu_A =$

$\sigma_A =$



Another Example



Three identical parts

Manufacturing process -- C_p = 1.5 (at least)

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What will the individual process σ_x be, if tolerances are obtained by simple division?

Find (i) standard deviation for the processes

(ii) tolerances for individual parts

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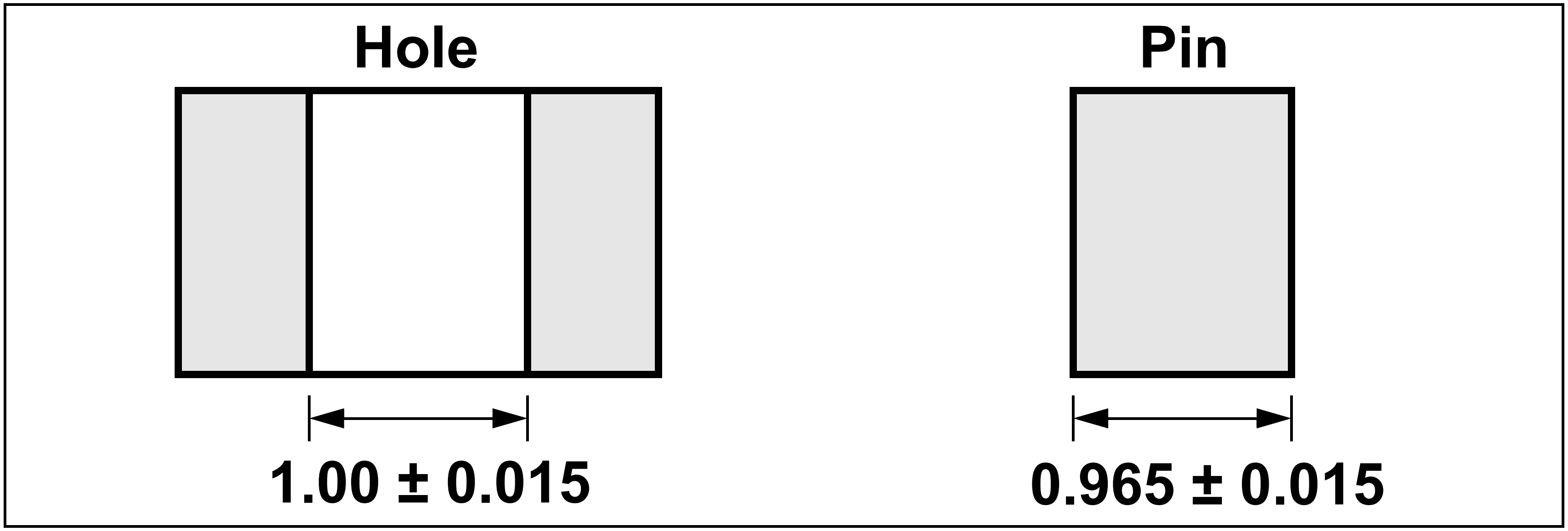
Another Example



For now, let's assume hole & pin producing processes are centered at the nominal values and that processes have Cp values of 1.0.

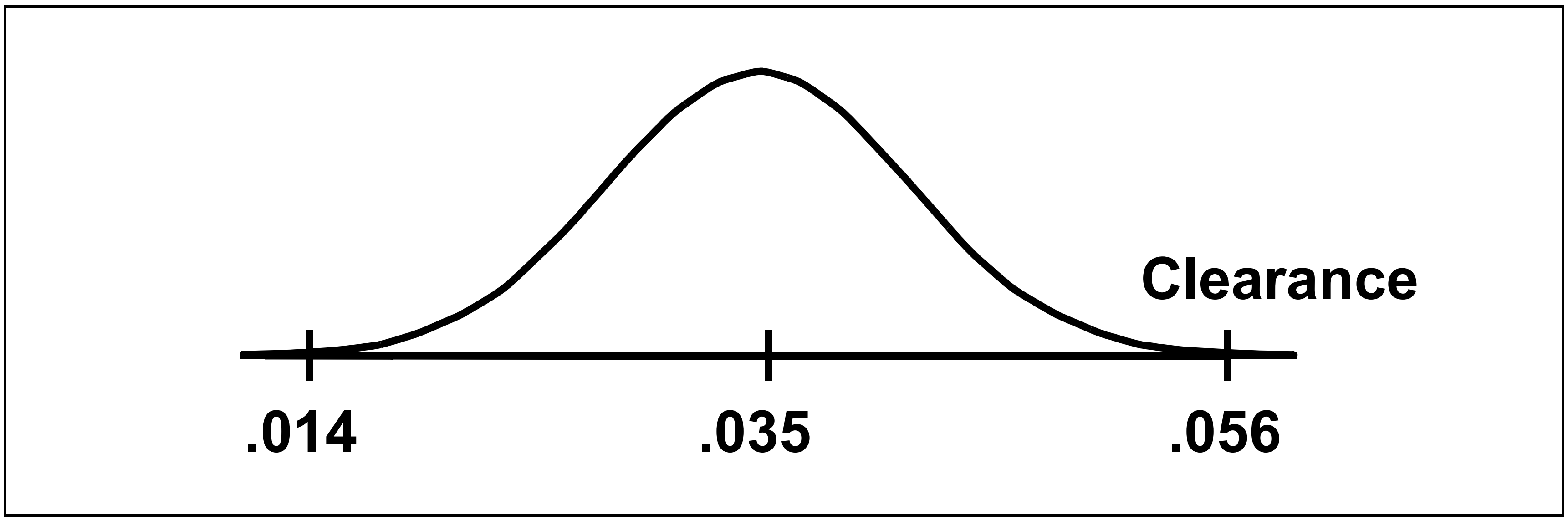
What does clearance dist. look like??

Clearance Distribution

C = H - P

$\mu_C = \mu_H - \mu_P$ = 0.035

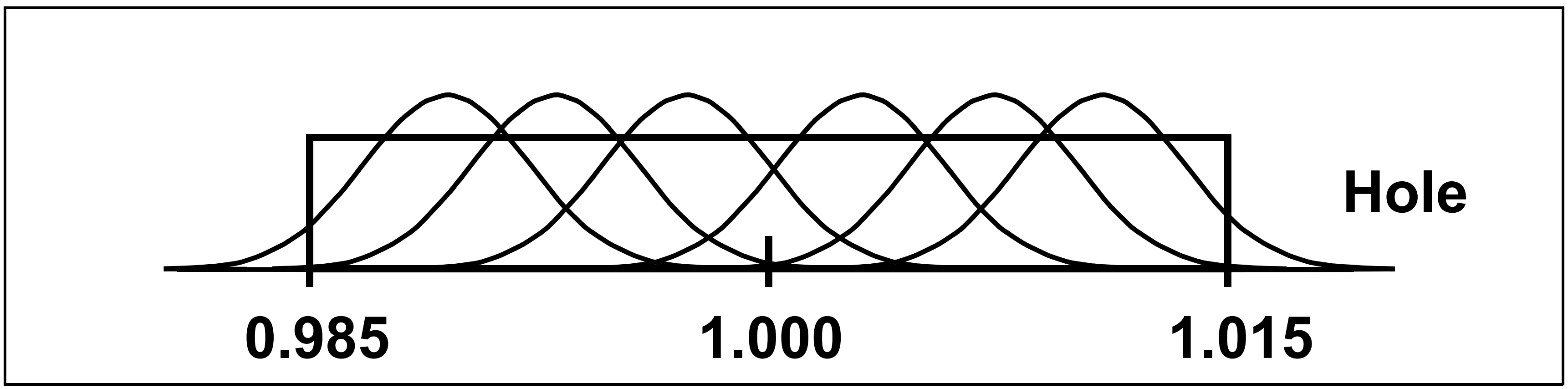
$\sigma_C^2 = \sigma_H^2 + \sigma_P^2$ ---- σ_c = 0.007



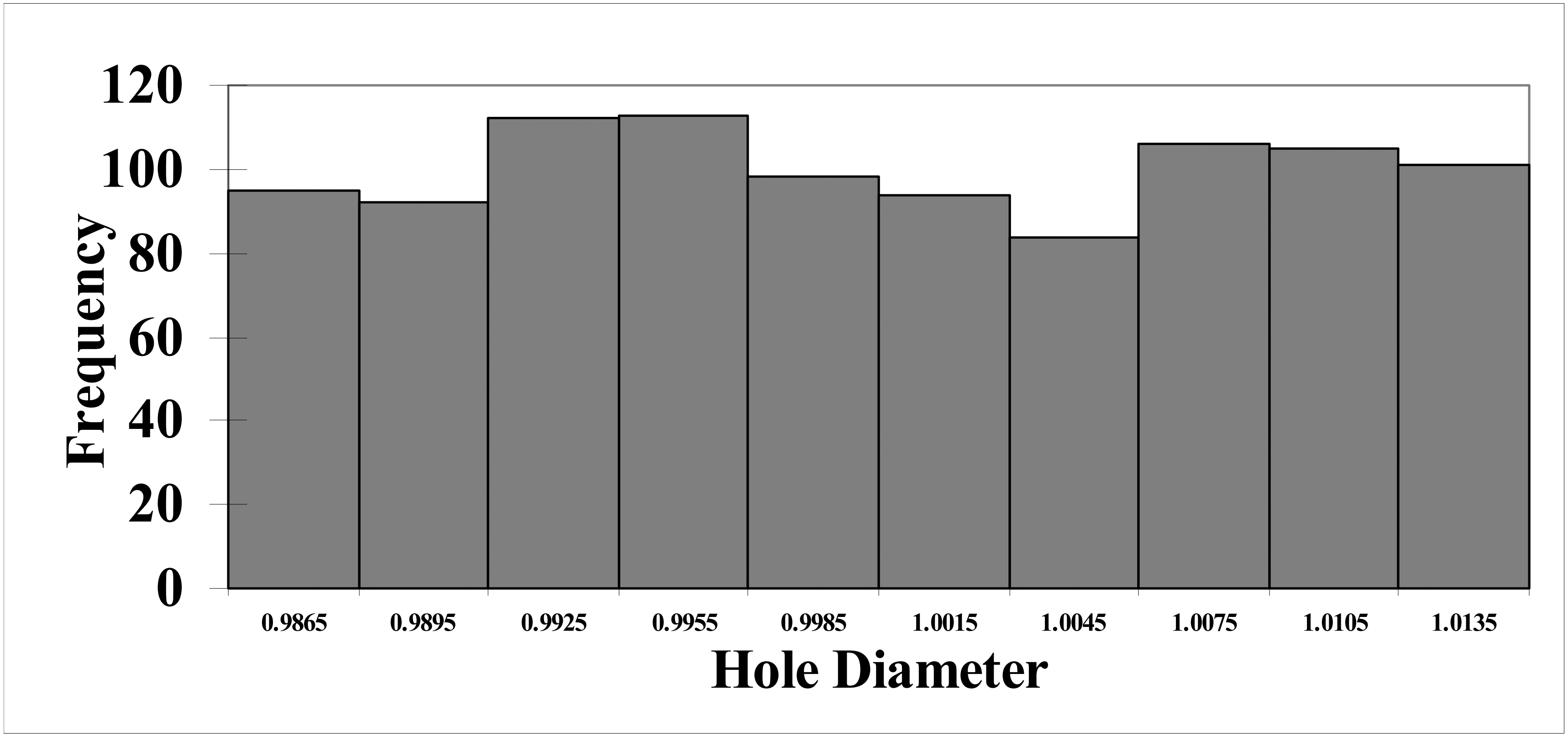
What can go Wrong?

- We have already seen that if our individual processes (in this case pin and hole) do not remain centered - the results can be disastrous.

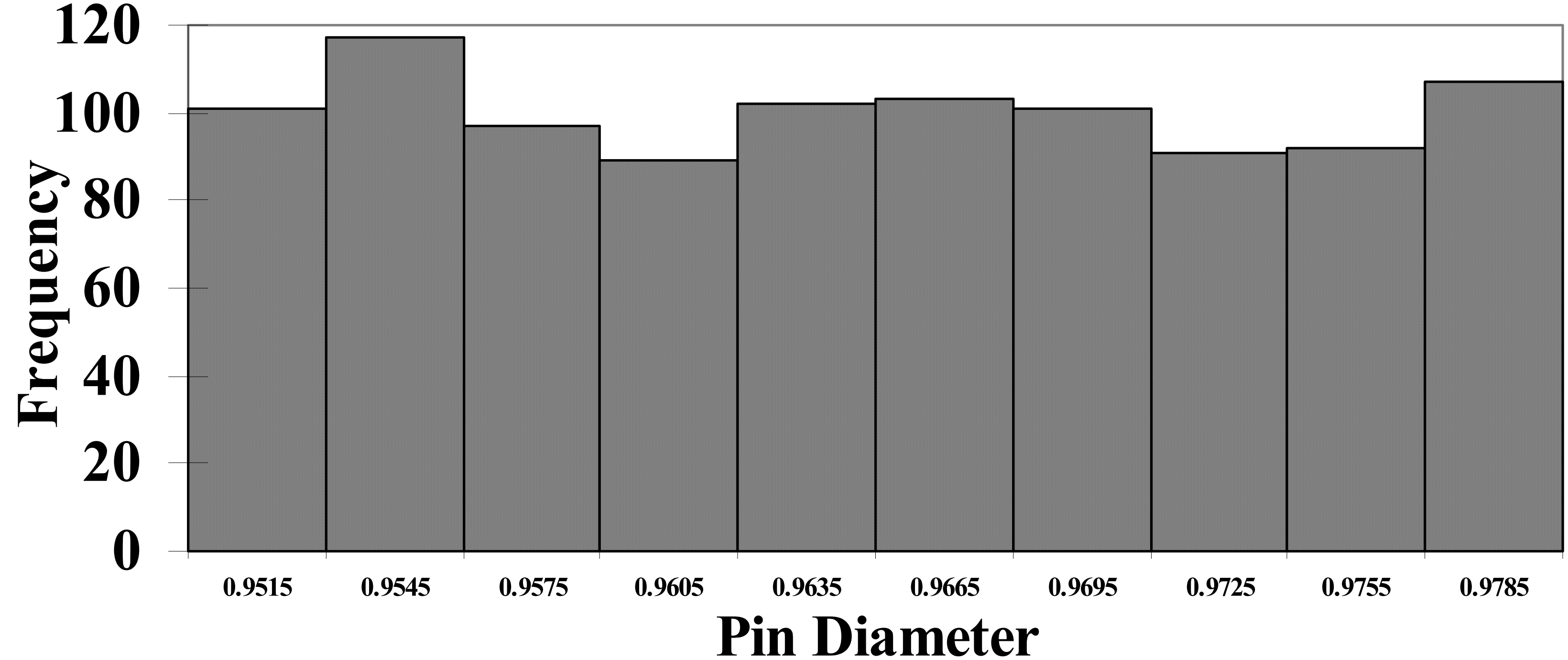
- What if our processes are not maintained in a state of statistical control?



Histogram - Hole Dimension



Histogram - Pin Dimension



Histogram - Clearance Dimension