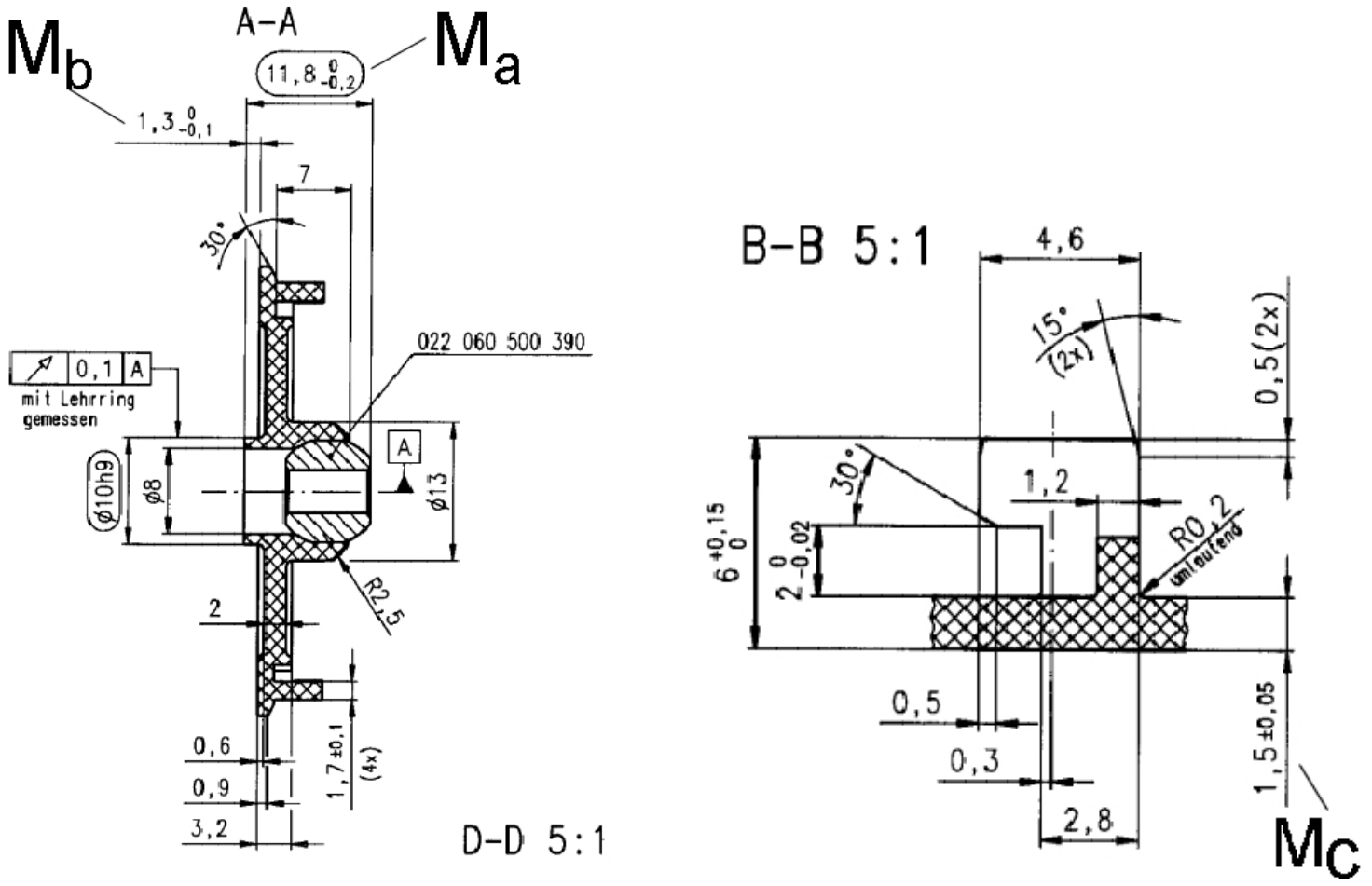
Tolerance Analysis and Cost Optimization

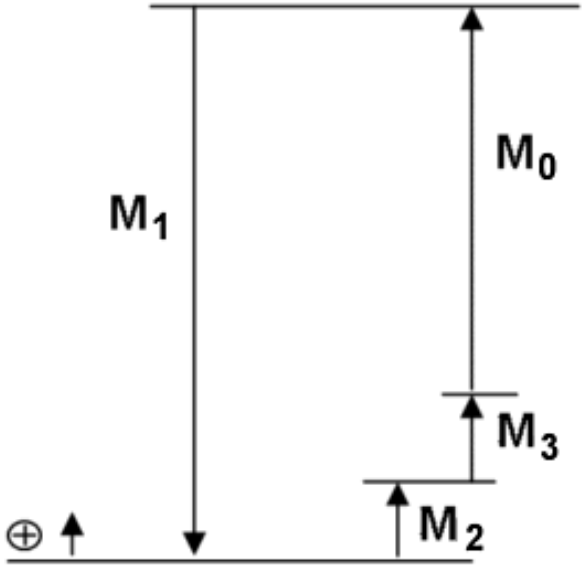


Tolerance Chain Problem

Given and Search:

- $M_0=M_1-M_2-M_3$ ➔ Nominal N_0 with T_0 and E_{C0} **?**
- $M_1=11,8 - 0,2$ ➔ $C_1=11,70$ with $T_1=0,2$
- $M_2= 1,3 – 0,1$ ➔ $C_2= 1,25$ with $T_2=0,1$
- $M_3= 1,5 \pm 0,05$ ➔ $C_3= 1,50$ with $T_3=0,1$

(C_i= Nominal / E_{ci}= Nominal Deviation / T_i=Tolerance)



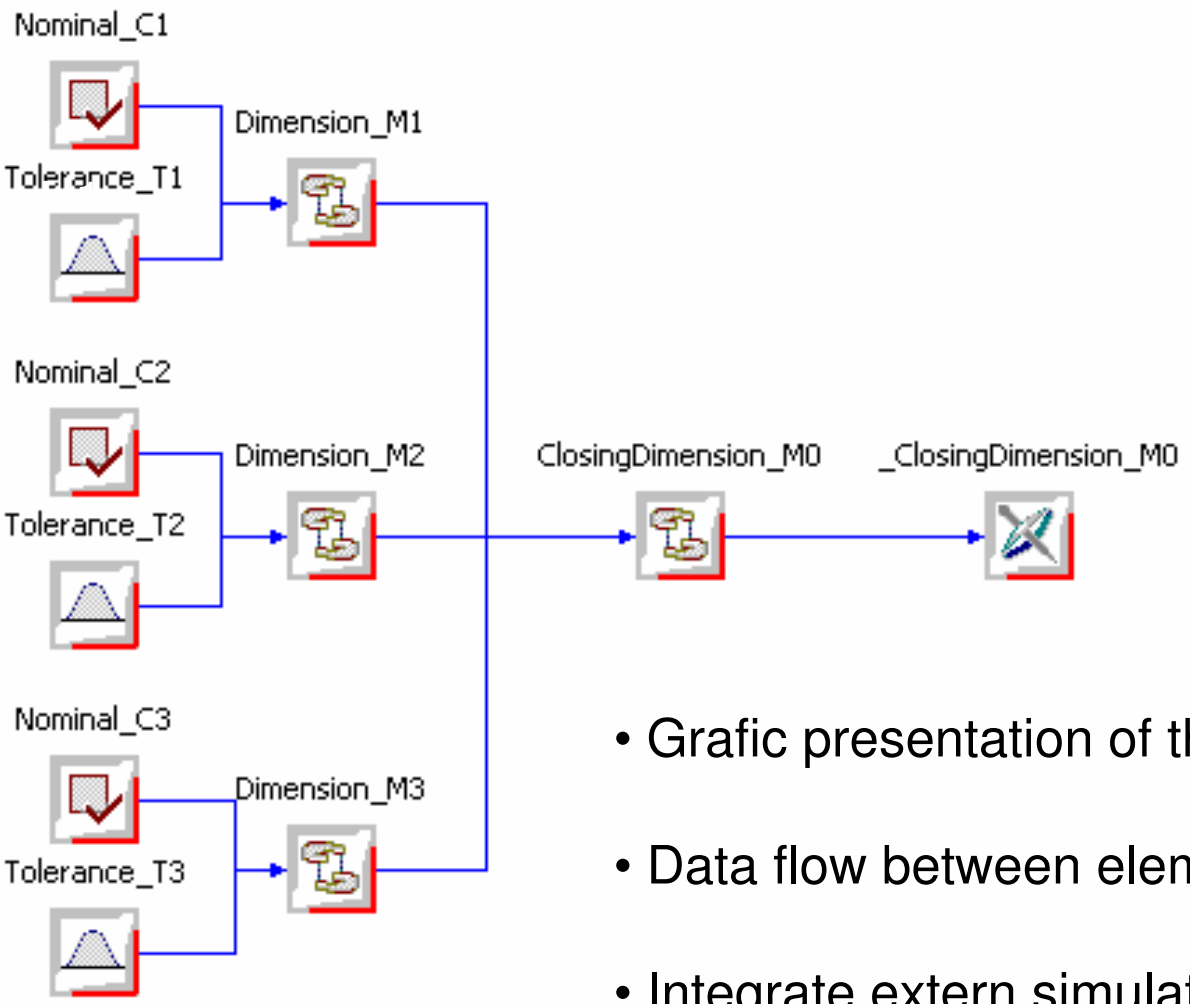
Analysis-goals:

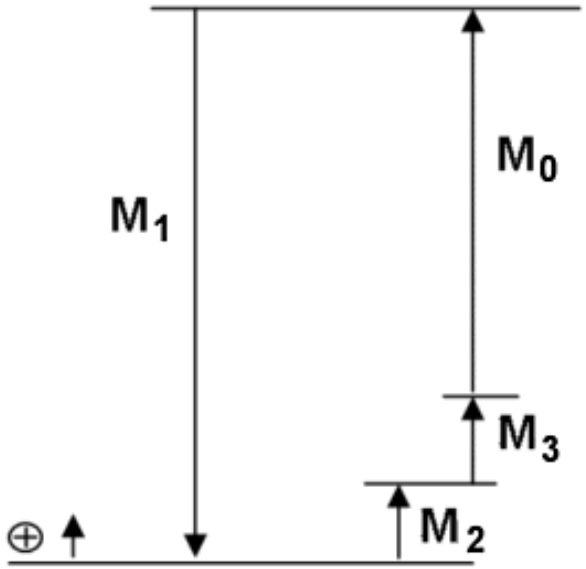
- Fulfill the given closing dimension?
  (Maximum-Minimum-Method)
- Probability Distribution of the closing dimension
  (Probability based Method)

Optimization goals:

- Set single tolerances at a given closing tolerance and the failure probability
- Reduce manufacturing cost maximizing the single tolerances

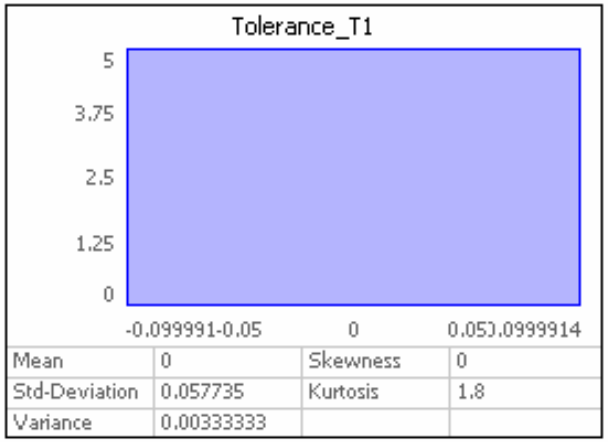
Workflow for Analysis and Optimization



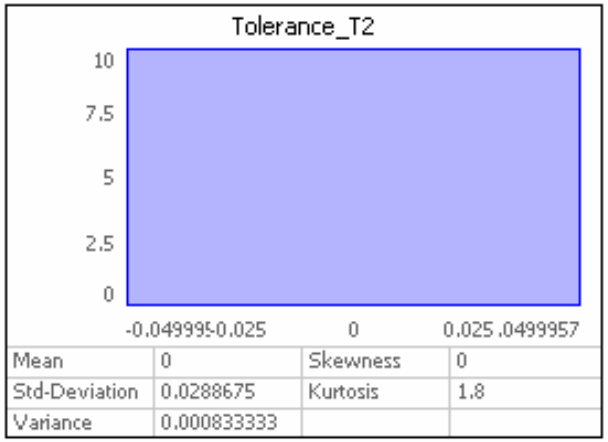


- Grafic presentation of the experiment
- Data flow between elements
- Integrate extern simulation systems

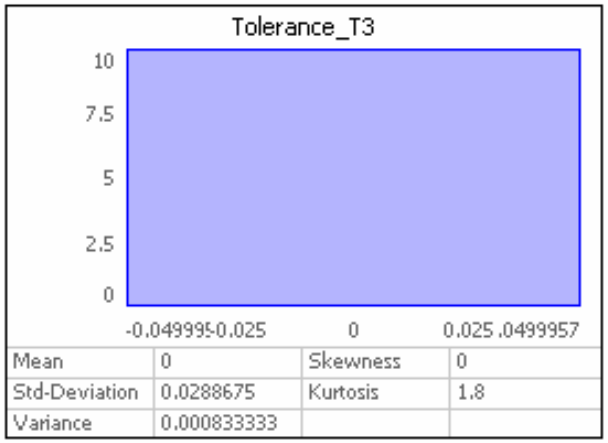
Maximum-Minimum-Method



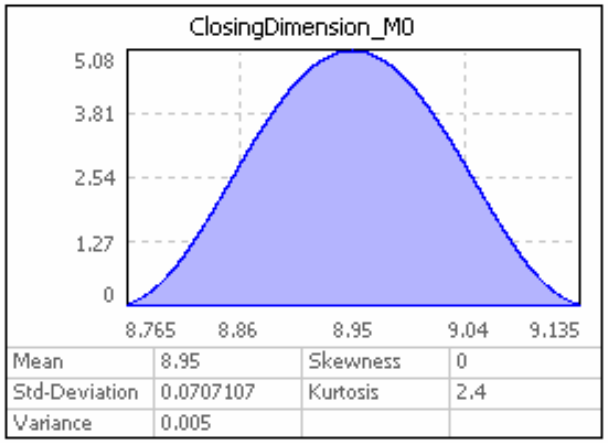
Mean	0	Skewness	0
Std-Deviation	0.057735	Kurtosis	1.8
Variance	0.00333333		



Mean	0	Skewness	0
Std-Deviation	0.0288675	Kurtosis	1.8
Variance	0.000833333		



Mean	0	Skewness	0
Std-Deviation	0.0288675	Kurtosis	1.8
Variance	0.000833333		



Mean	8.95	Skewness	0
Std-Deviation	0.0707107	Kurtosis	2.4
Variance	0.005		

Worst-Case is considered

100% manufactured parts fall in closing tolerance

Dimension $\mathbf{N_0}$ of Nominal $\mathbf{N_i}$:

$\mathbf{N_0} = -1 \cdot (1{,}5 + 1{,}3 - 11{,}8) = 9{,}0$

Nominal Deviation $\mathbf{E_{c0}}$ of $\mathbf{E_{ci}}$:

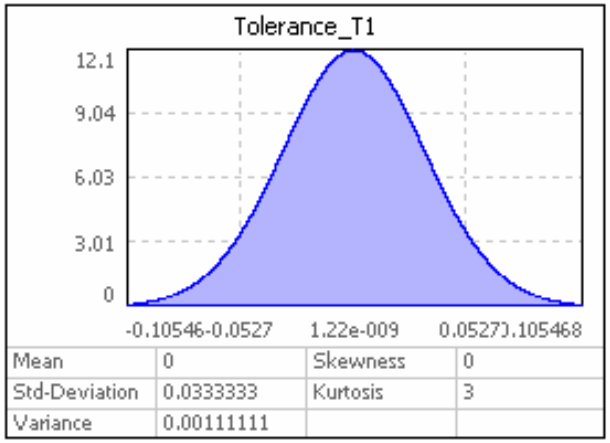
$\mathbf{E_{c0}} = -1 \cdot (0 - 0{,}05 + 0{,}1) = -0{,}05$

Tolerance $\mathbf{T_0}$ of the sum $\mathbf{T_i}$:

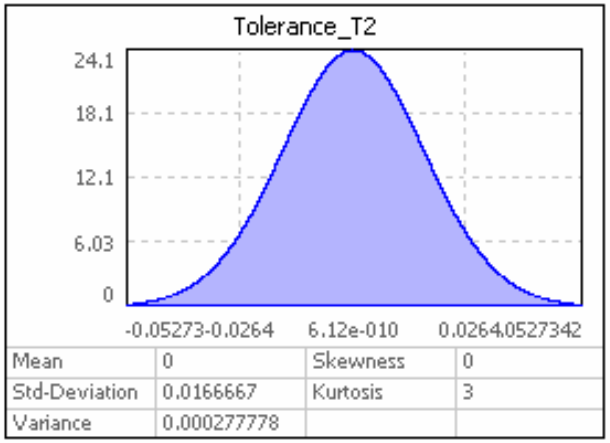
$\mathbf{T_0}=0{,}2+0{,}1+0.1=0{,}4$

Closing Dimension $\mathbf{M_0}=8{,}95\pm0{,}2$

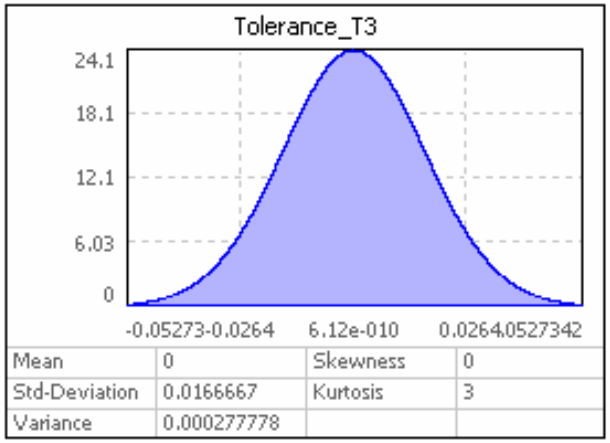
Probability Based Method



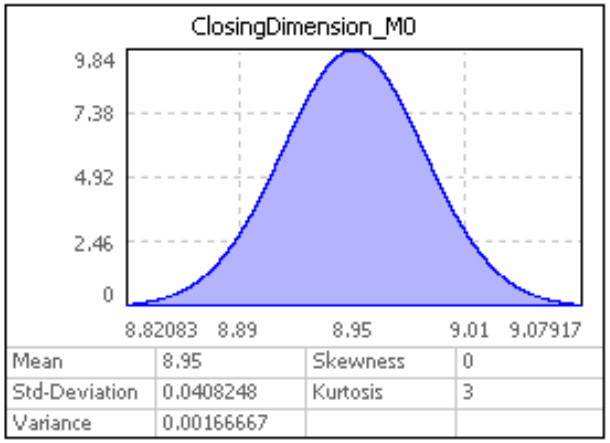
Mean	0	Skewness	0
Std-Deviation	0.0333333	Kurtosis	3
Variance	0.00111111		



Mean	0	Skewness	0
Std-Deviation	0.0166667	Kurtosis	3
Variance	0.000277778		



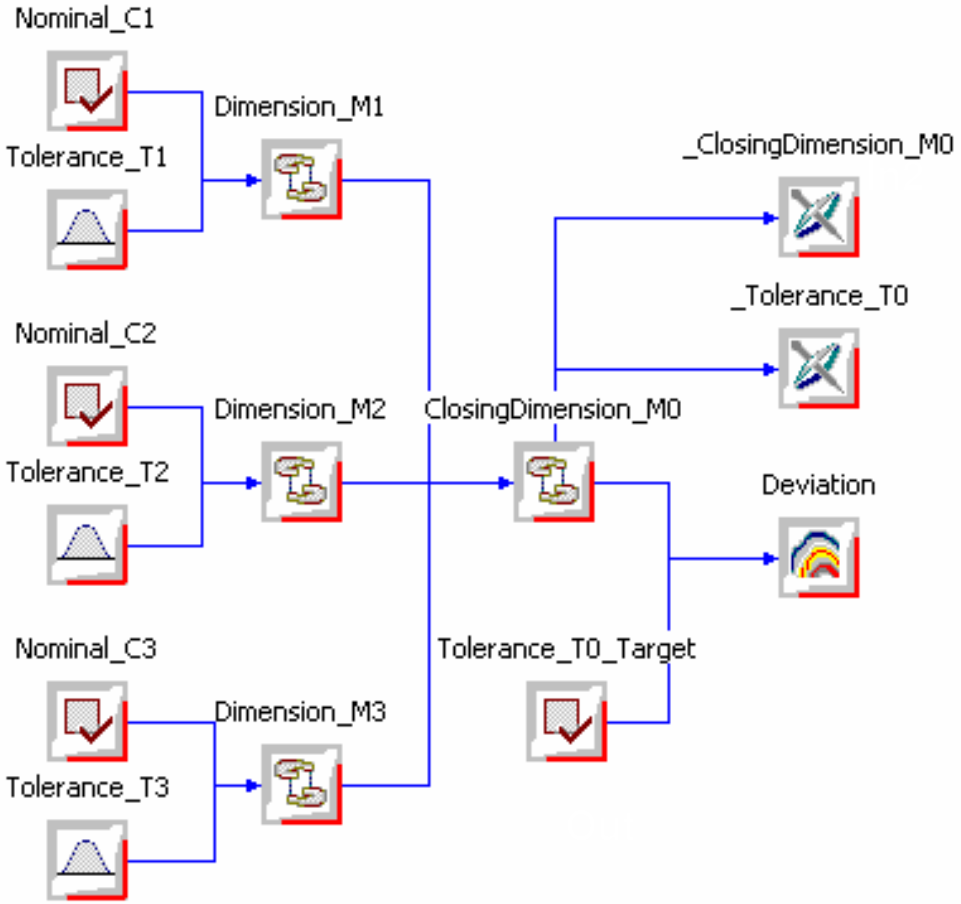
Mean	0	Skewness	0
Std-Deviation	0.0166667	Kurtosis	3
Variance	0.000277778		

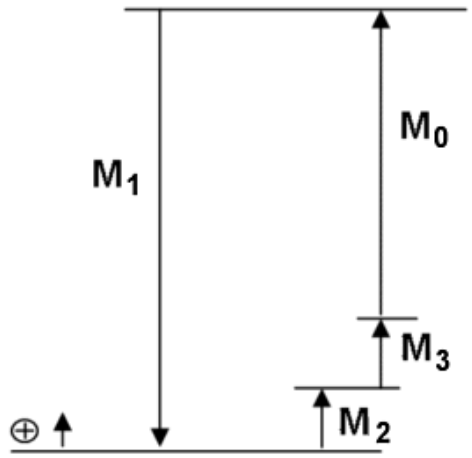


Mean	8.95	Skewness	0
Std-Deviation	0.0408248	Kurtosis	3
Variance	0.00166667		

- The probability of the closing dimension is considered.
- The failure probability is 0.3 % (99.7 % manufactured parts fall in closing tolerance)

Tolerance-Cost-Optimization



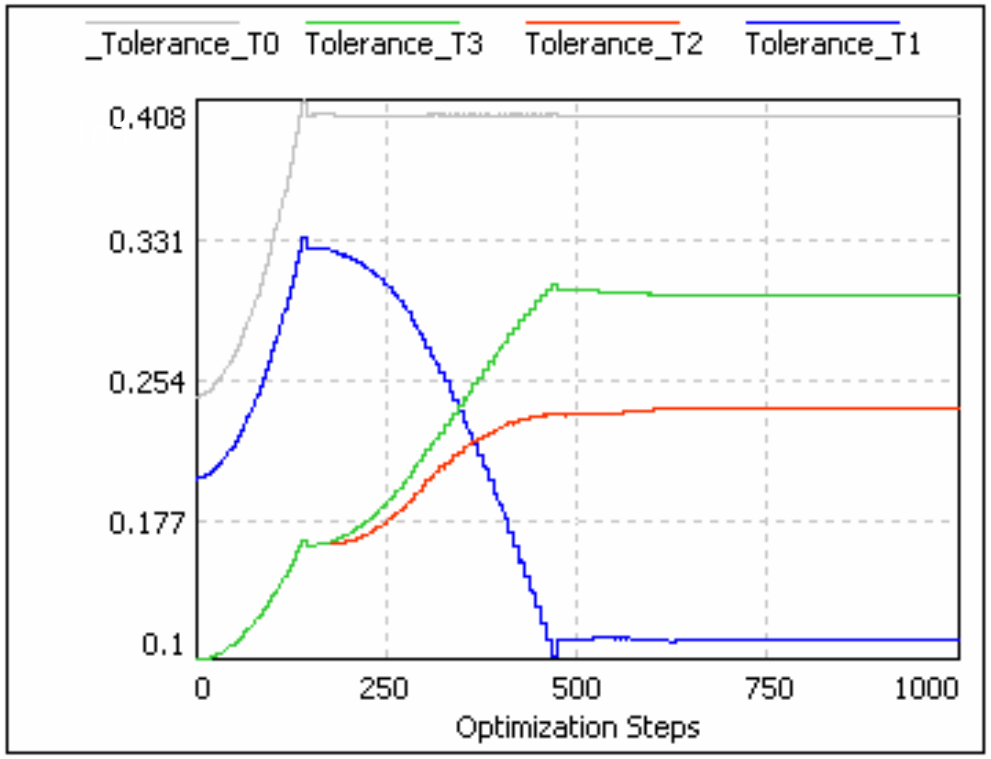


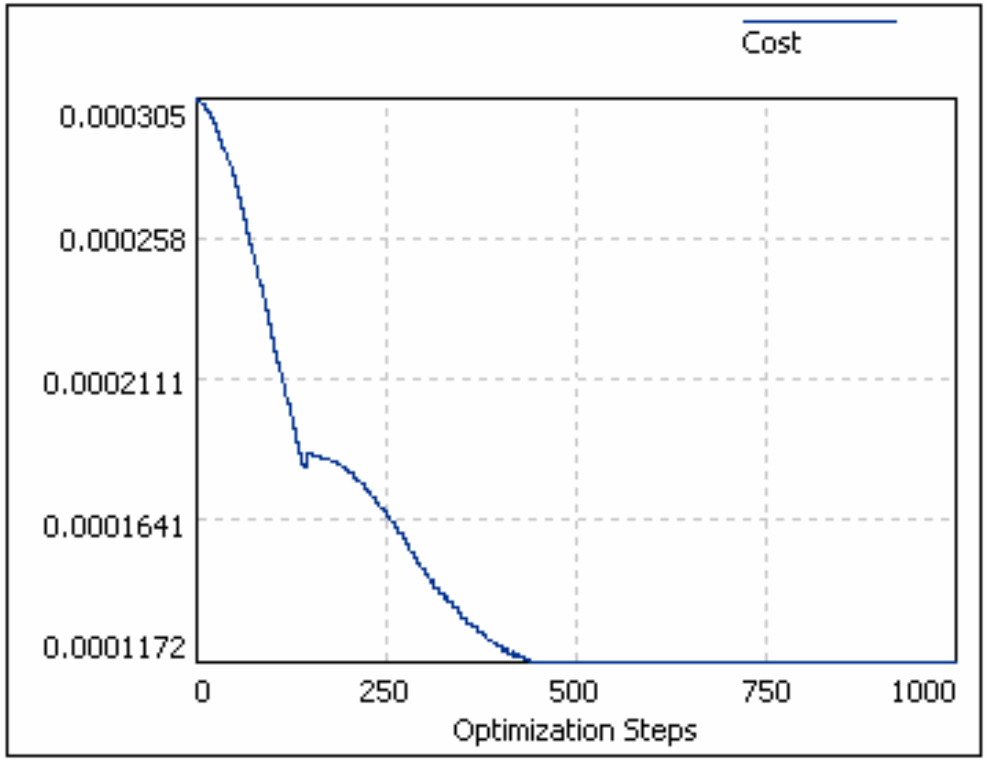
Given and Search:

- $M_0=M_1-M_2-M_3$
- $C_0=8,75$ with $T_0=0,4$ **!**
- $C_1=11,70$ with $T_1=0,05 \ldots T_0$ **?**
- $C_2= 1,25$ with $T_2=0,05 \ldots T_0$ **?**
- $C_3= 1,50$ with $T_3=0,05 \ldots T_0$ **?**

(C_i= Nominal / E_{ci}= Nominal Deviation / T_i=Tolerance)

Optimization Process





Different cost factors: T1= 1, T2=10, T3=20