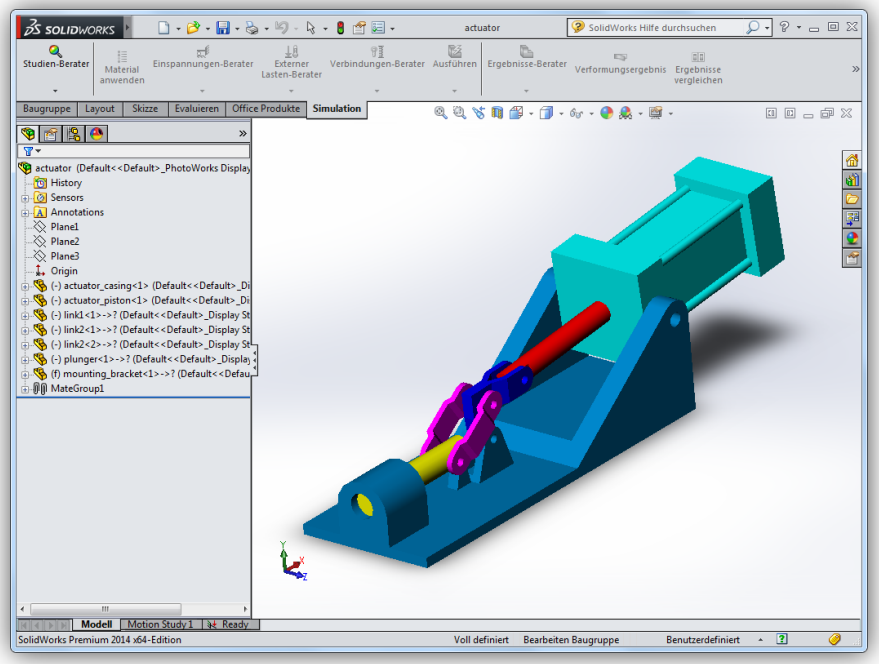
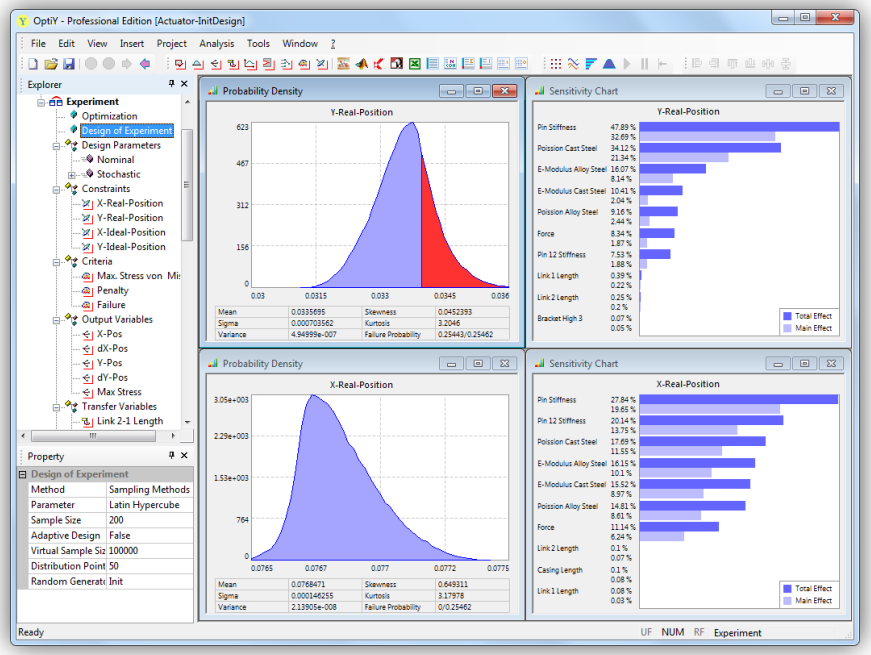
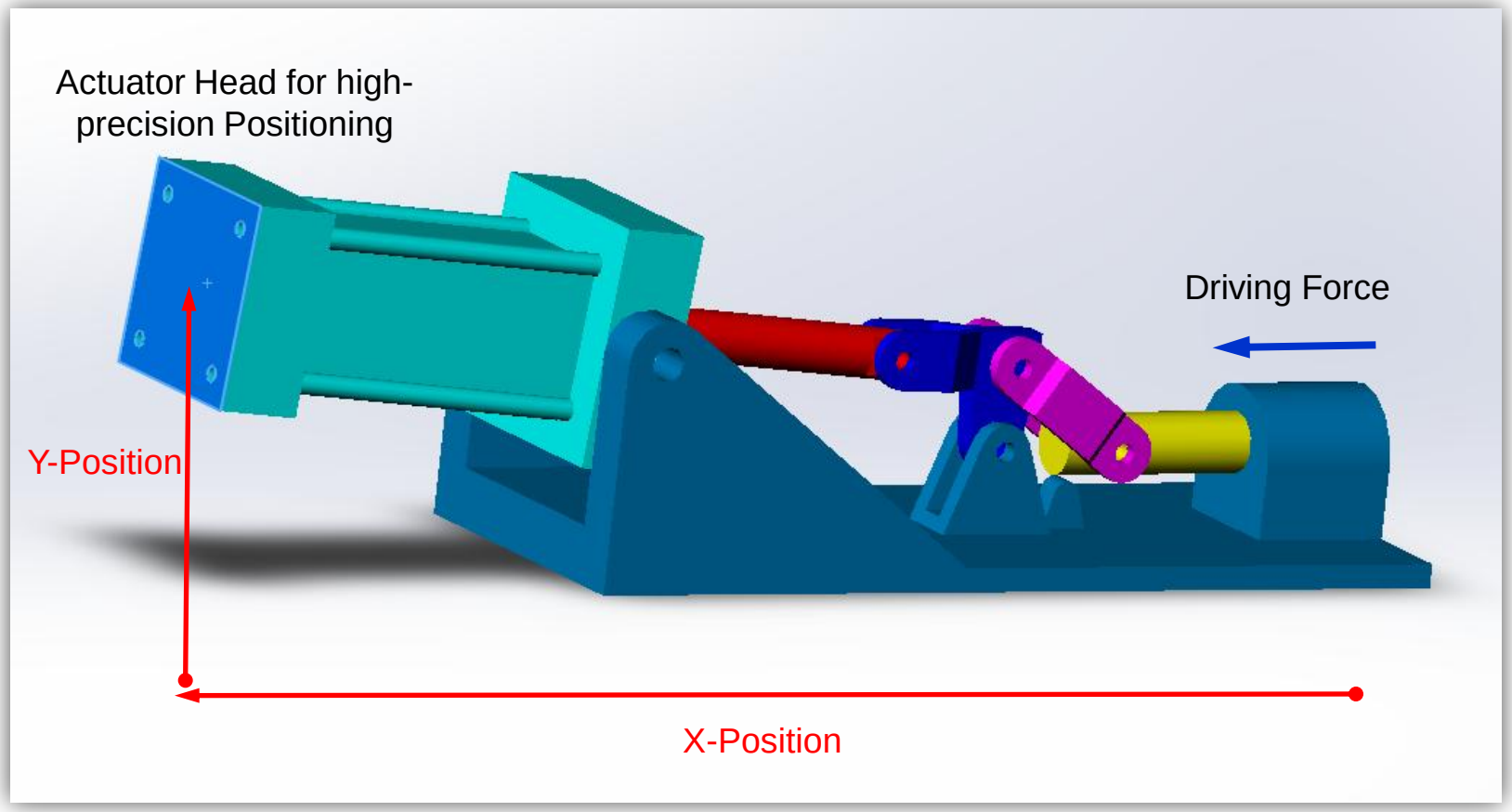
# Robust Design of an Actuator Assembly for high-precision Positioning under static Aspect

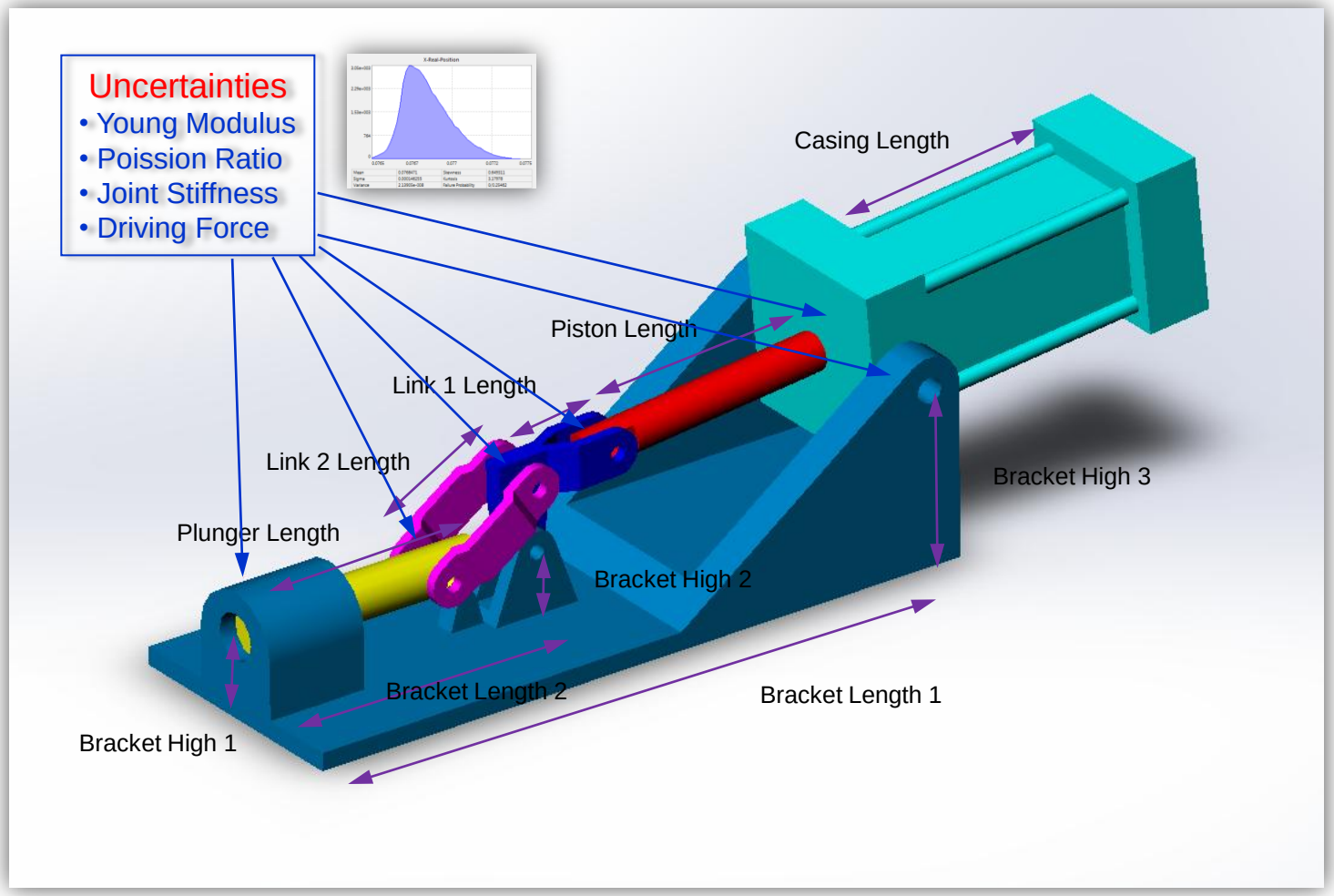


# Actuator Assembly in SolidWorks®



# Design Parameters and Uncertainties



# Design Space and Specifications

Design Parameters

| Name | Nominal | Tolerance | Unit |
|---|---|---|---|
| Plunger Length | 0.058890916 | 0.004 | m |
| Bracket High 1 | 0.03048 | 0.004 | m |
| Bracket High 2 | 0.0196819364 | 0.004 | m |
| Link 2 Length | 0.01476502 | 0.004 | m |
| Piston Length | 0.1016 | 0.004 | m |
| Link 1 Length | 0.00635 | 0.0008 | m |
| Casing Length | 0.05939536 | 0.004 | m |
| Bracket Length 1 | 0.171704 | 0.004 | m |
| Bracket High 3 | 0.0427736 | 0.004 | m |
| Bracket Length 2 | 0.09518904 | 0.004 | m |
| E-Modulus Alloy Steel | 2.1e+011 | 20000 | N/m^2 |
| Poission Alloy Steel | 0.28 | 0.001 | |
| E-Modulus Cast Steel | 1.9e+011 | 20000 | N/m^2 |
| Poission Cast Steel | 0.26 | 0.001 | |
| Pin Stiffness | 1000000 | 2000 | lb/in |
| Pin 12 Stiffness | 500 | 1 | lb/in |
| Force | 15 | 1 | lbf |

**Design Constraints**

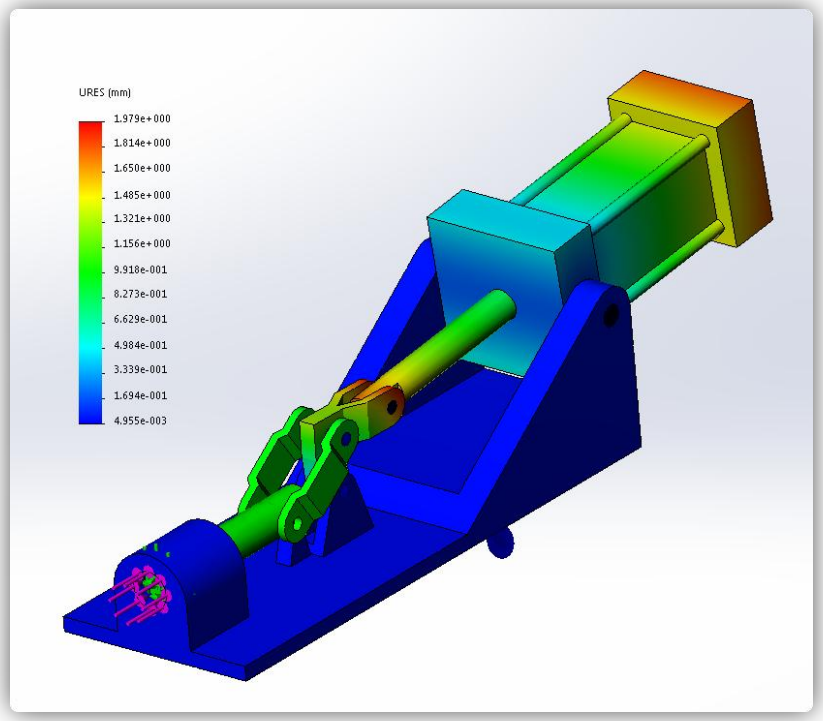
- All Geometry Tolerances = 0,1 mm
- Actuator Head Positioning:
  - 75 mm ≤ X-Position ≤ 79 mm
  - 30 mm ≤ Y-Position ≤ 34 mm

Design parameter with variable nominal and fixed tolerance (0,1 mm)

For each parameter:
- Design range = 4 mm
- Design center = nominal value

Design uncertainties with fixed nominal and fixed tolerance

# Nominal Design: Nominal FEM-Simulation in SolidWorks ®




Nominal Deformation under Static Load

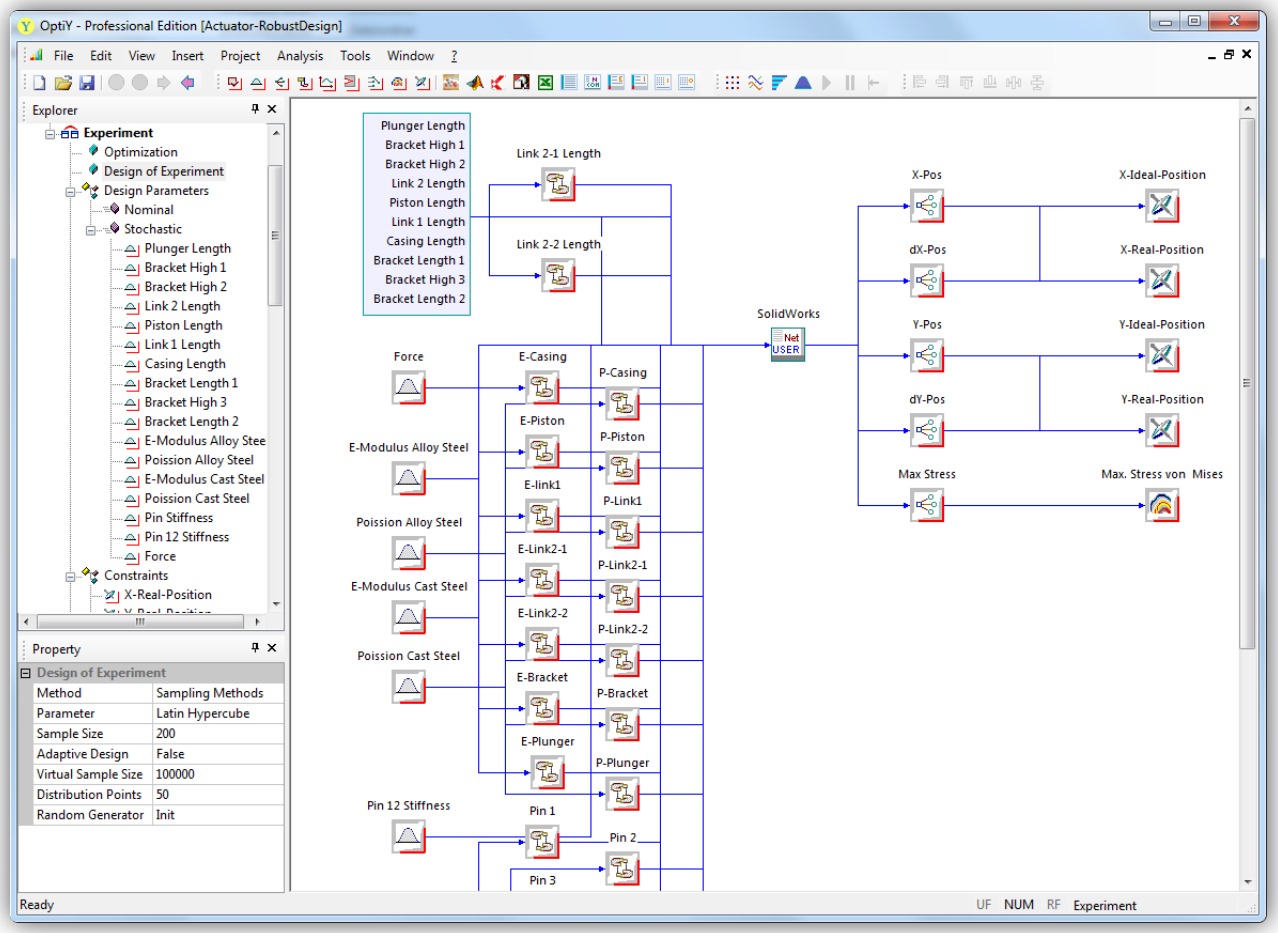
Design Parameters

| Name | Nominal | Unit |
|---|---|---|
| Plunger Length | 0.058890916 | m |
| Bracket High 1 | 0.03048 | m |
| Bracket High 2 | 0.0196819364 | m |
| Link 2 Length | 0.01476502 | m |
| Piston Length | 0.1016 | m |
| Link 1 Length | 0.00635 | m |
| Casing Length | 0.05939536 | m |
| Bracket Length 1 | 0.171704 | m |
| Bracket High 3 | 0.0427736 | m |
| Bracket Length 2 | 0.09518904 | m |
| E-Modulus Alloy Steel | 2.1e+011 | N/m^2 |
| Poission Alloy Steel | 0.28 | |
| E-Modulus Cast Steel | 1.9e+011 | N/m^2 |
| Poission Cast Steel | 0.26 | |
| Pin Stiffness | 1000000 | lb/in |
| Pin 12 Stiffness | 500 | lb/in |
| Force | 15 | lbf |

Nominal model parameters without tolerances for nominal simulation

Idealistic Position = Geometry Position
(X-Position= 0.07712 m; Y-Position=0.03111 m)
Realistic Position = Geometry Position + Static Deformation
(X-Position = 0.07735 m; Y-Position = 0.03246 m)

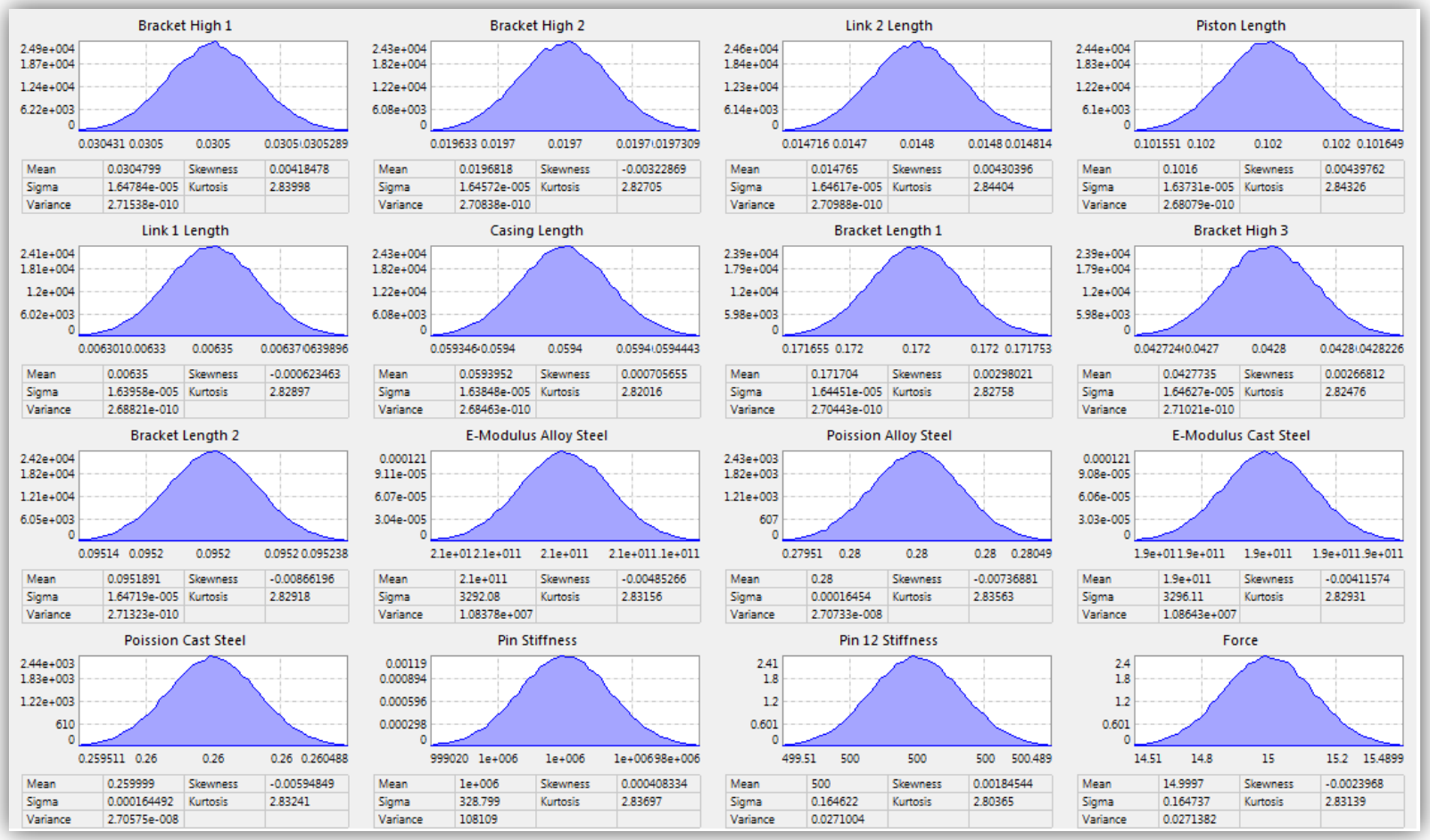
# Process Work Flow in OptiY ®



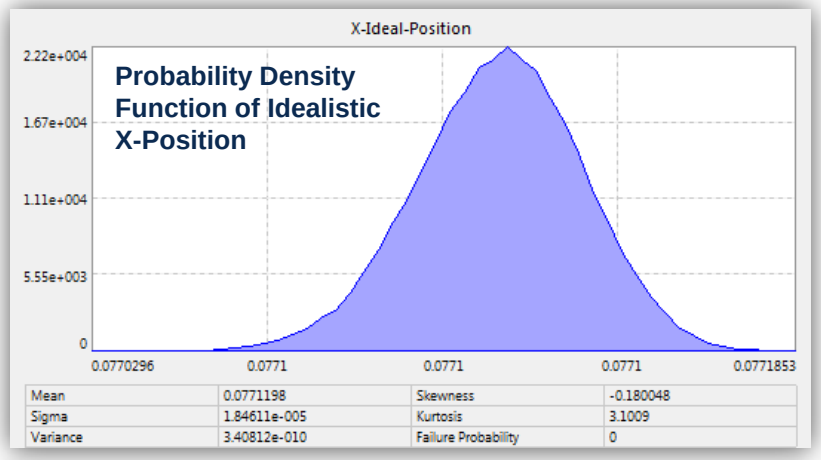

**OptiY starts a loop of several calculations (DOE) automatically using the direct integration node Solidworks:**

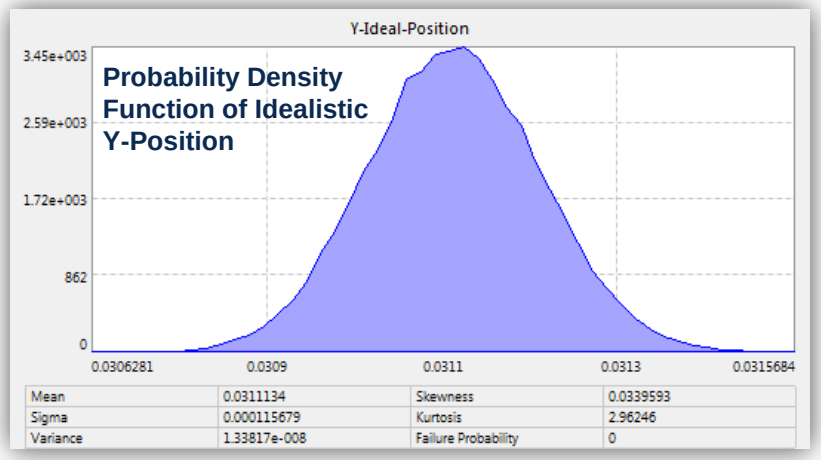
- Generate distributed values for stochastic parameters in OptiY
- Put the parameter values from OptiY to SolidWorks
- Update the parameters, rebuild the assembly, check geometry constraints and interferences in SolidWorks
- Start static FEM-simulation for the new assembly in SolidWorks and update sensor data from simulation
- Read the sensor data from SolidWorks und put them to the output parameters of OptiY

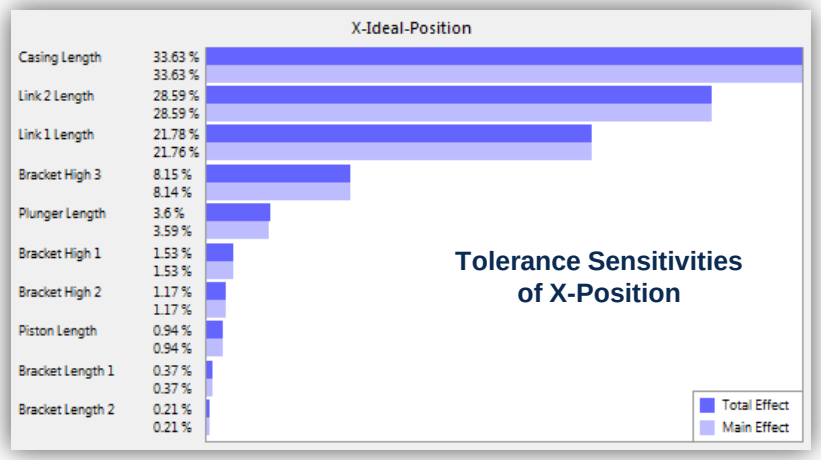
# Stochastic Distribution of Model Parameters

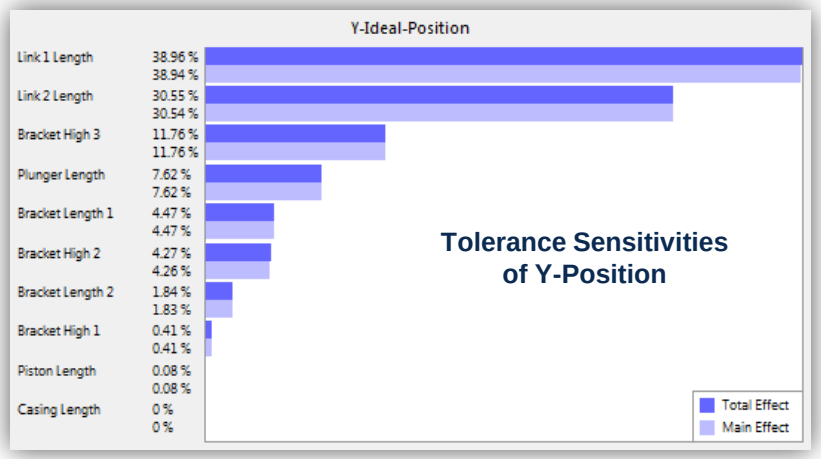


# Geometry Tolerance Analysis without Uncertainties



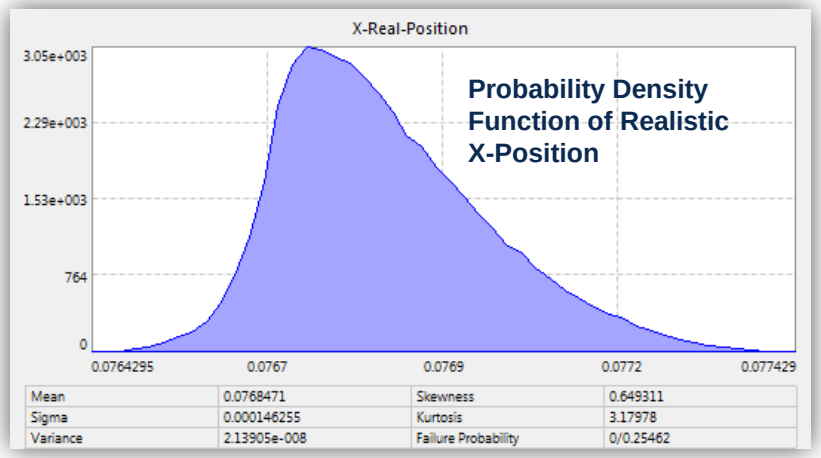



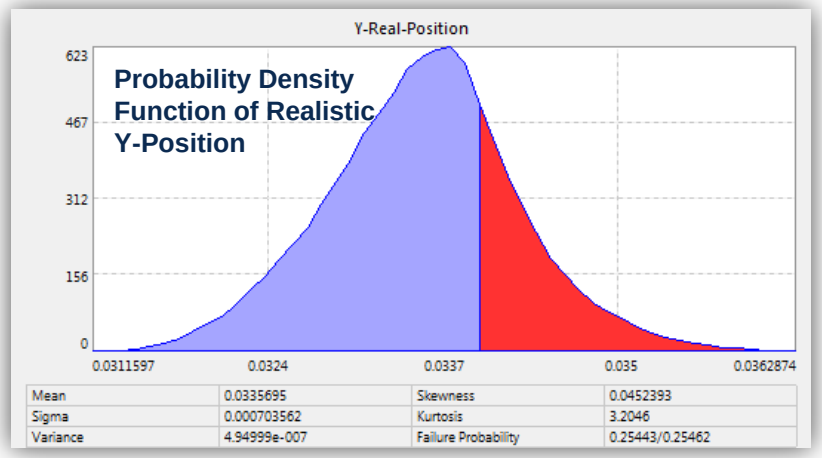



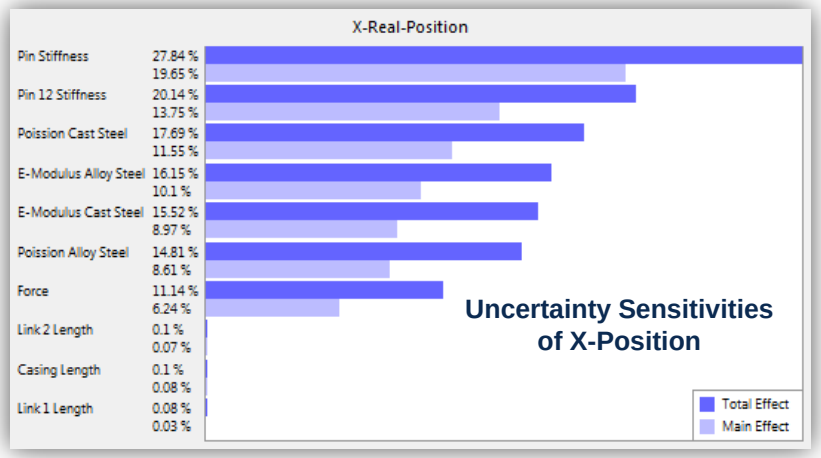

**Total Failure Probability = 0%**

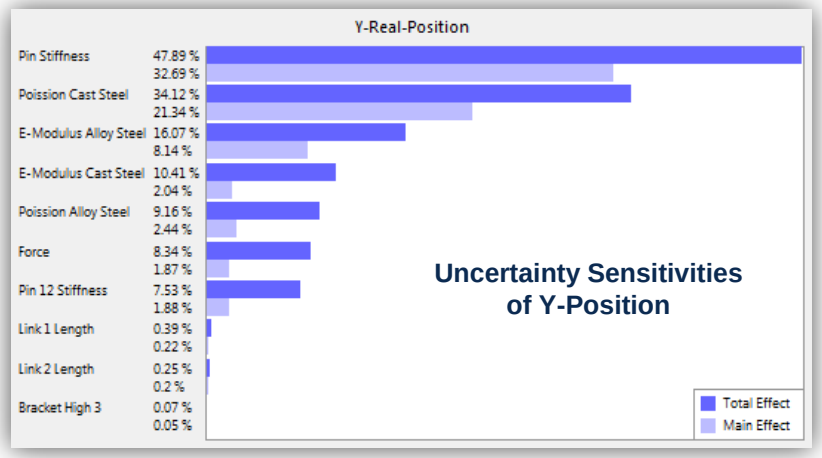
0.03 m ≤ Y-Position ≤ 0.034 m

# Probabilistic Simulation for Nominal Design with Uncertainties



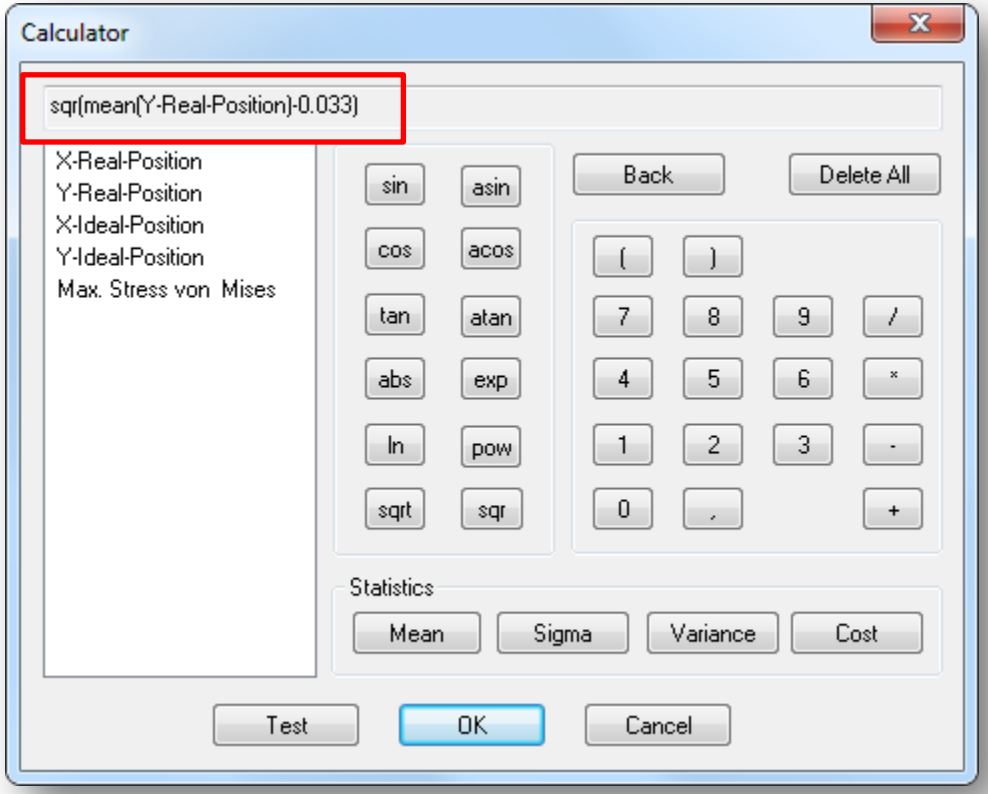




**Total Failure Probability = 24,44%**

0.03 m ≤ Y-Position ≤ 0.034 m

# Robust Design Optimization



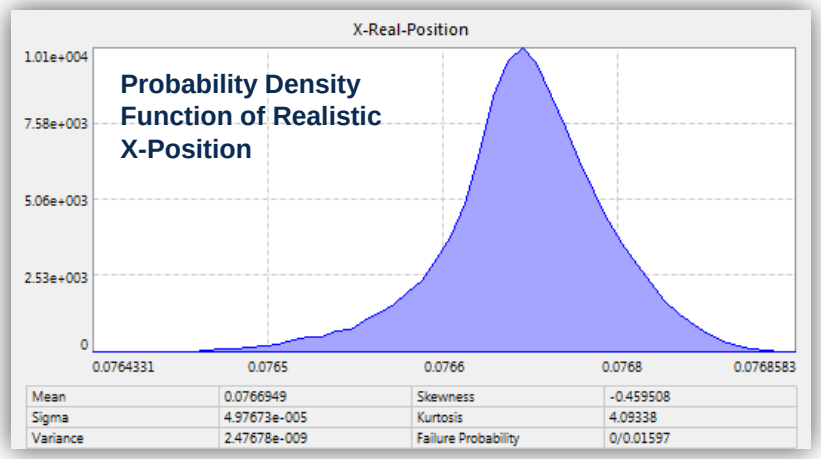

**Optimization Results:**
Optimal nominal values of the design parameters with the same tolerances

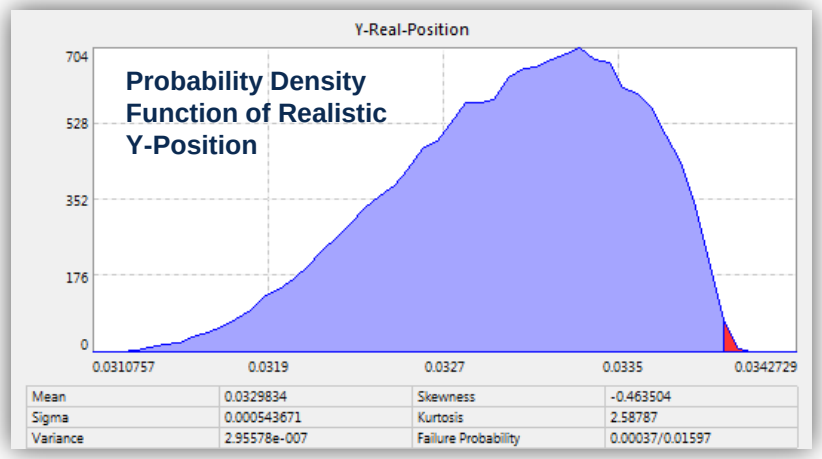
Design Parameters

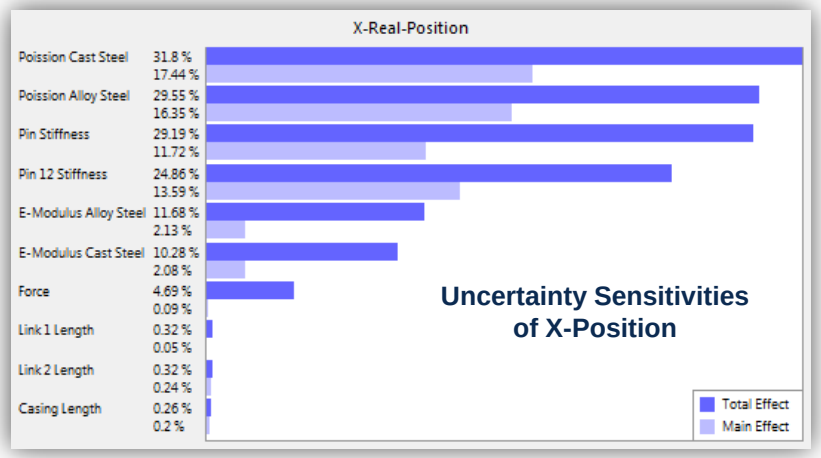
| Name | Nominal | Tolerance | Unit |
|---|---|---|---|
| Plunger Length | 0.0582091056 | 0.0001 | m |
| Bracket High 1 | 0.0301781307 | 0.0001 | m |
| Bracket High 2 | 0.0200466009 | 0.0001 | m |
| Link 2 Length | 0.0145313329 | 0.0001 | m |
| Piston Length | 0.100607309 | 0.0001 | m |
| Link 1 Length | 0.00646276975 | 0.0001 | m |
| Casing Length | 0.0596912884 | 0.0001 | m |
| Bracket Length 1 | 0.172206599 | 0.0001 | m |
| Bracket High 3 | 0.0423728163 | 0.0001 | m |
| Bracket Length 2 | 0.0952262386 | 0.0001 | m |
| E-Modulus Alloy Steel | 2.1e+011 | 20000 | N/m^2 |
| Poission Alloy Steel | 0.28 | 0.001 | |
| E-Modulus Cast Steel | 1.9e+011 | 20000 | N/m^2 |
| Poission Cast Steel | 0.26 | 0.001 | |
| Pin Stiffness | 1000000 | 2000 | lb/in |
| Pin 12 Stiffness | 500 | 1 | lb/in |
| Force | 15 | 1 | lbf |

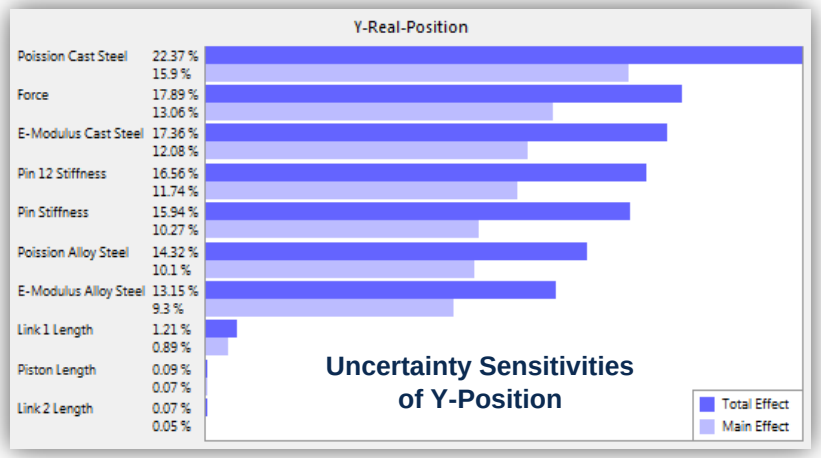
Robust Design Goal to Minimize the Failure Probability using Taguchi Quality Loss Function. Center point = 0.033 m for Y-position because of its unsymmetrical distribution (0.03 m ≤ Y-Position ≤ 0.034 m)

# Probabilistic Simulation for Robust Design



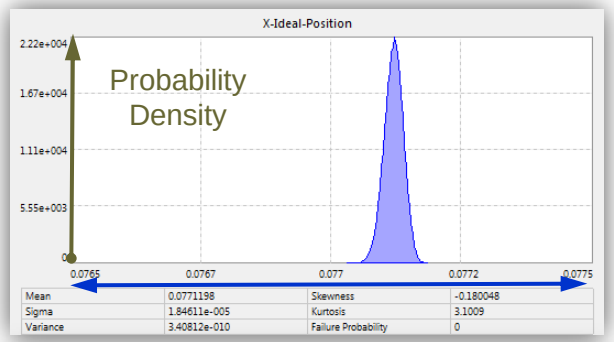



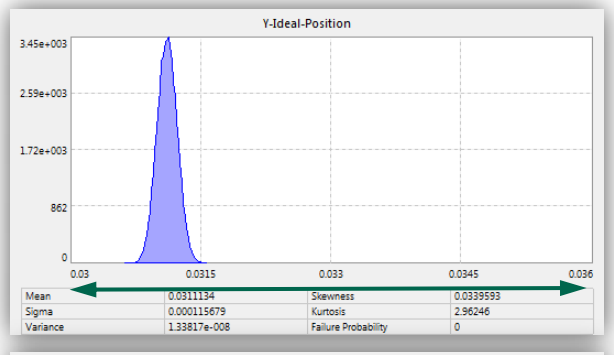



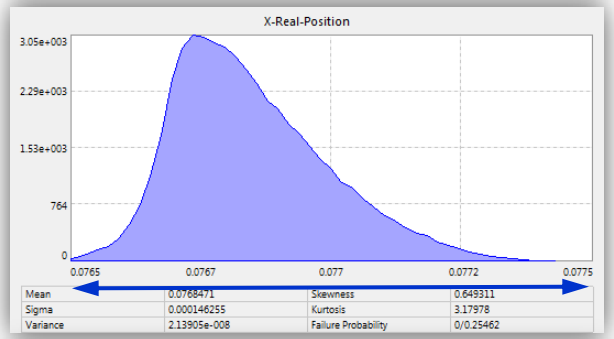

**Total Failure Probability = 0,04%**

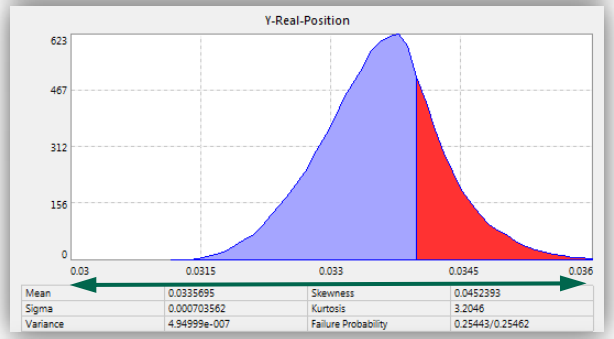
0.03 m ≤ Y-Position ≤ 0.034 m

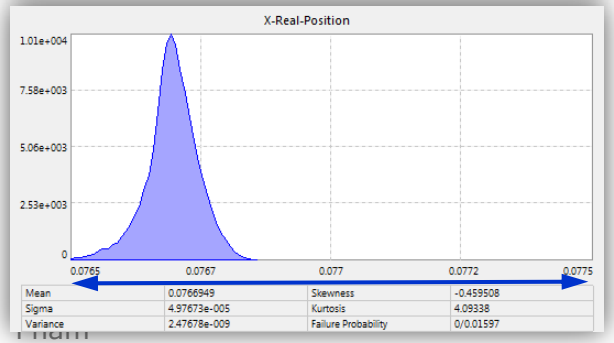
# Same-Scale PDF Comparison between Designs

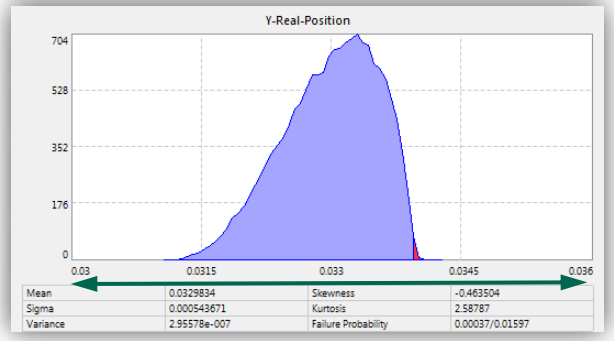



Nominal Design
only by Geometry Tolerances
without Uncertainties
Failure Probability = 0%

Nominal Design
with Uncertainties
Failure Probability = 25,44%

Robust Design
with Uncertainties
Failure Probability = 0,04%

www.optiy.eu



X-Position: [0.0765 – 0.0775] m

Y-Position: [0.030 – 0.036] m

# Conclusion

Nominal design using classical nominal simulation cannot warranty the reliability and quality of the products, because the nominal parameters are only one fix value.

Robust design is a power-full tool for design of reliable and quality product in the early design stage without any cost. It considers the uncertainty parameters as stochastic distributions.

In the case of the actuator assembly, the failure probability has been reduced from **25,44% to 0,04%** for the manufacturing process.

**OptiY®** is the leading software platform for robust design of all engineering fields using different commercial CAD/CAE-software or in-house codes.