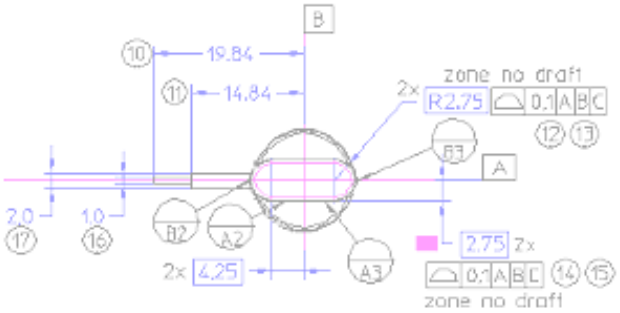

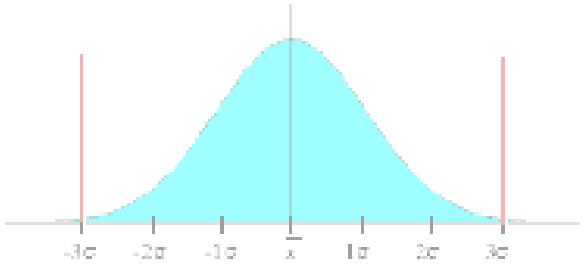

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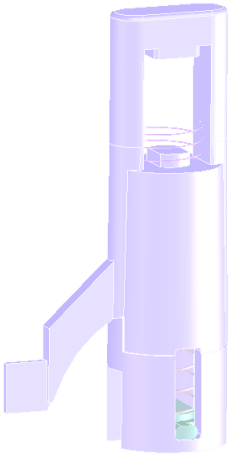
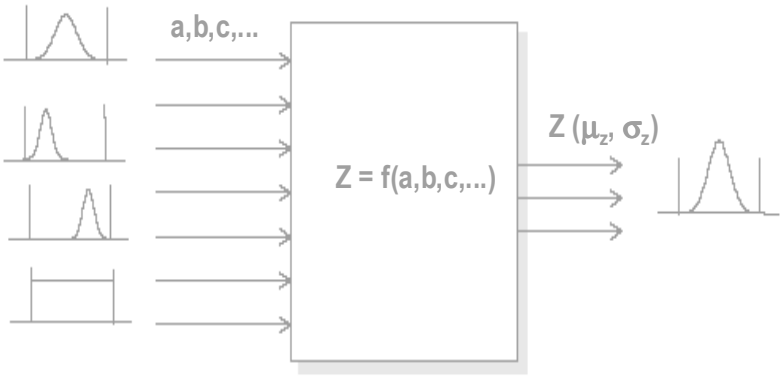
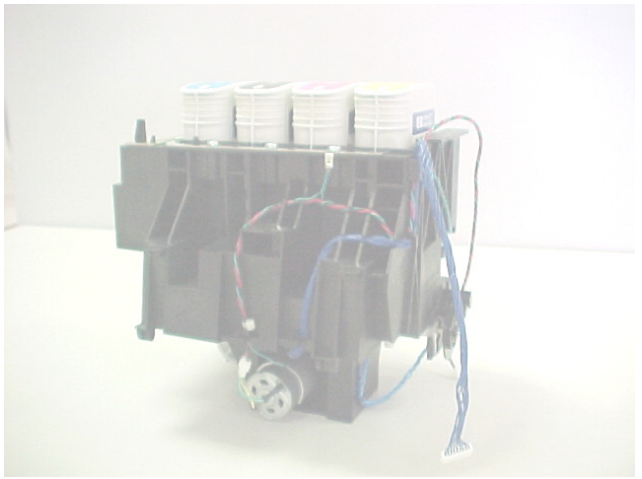
Functional Tolerancing & Worstcasing





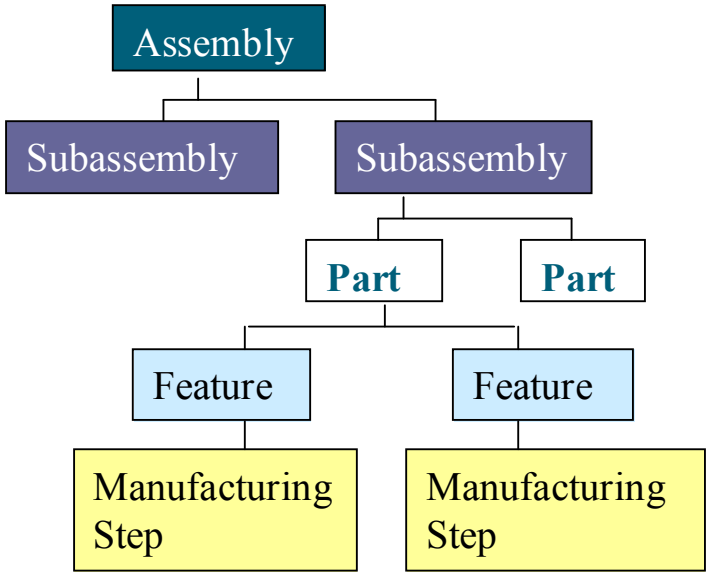


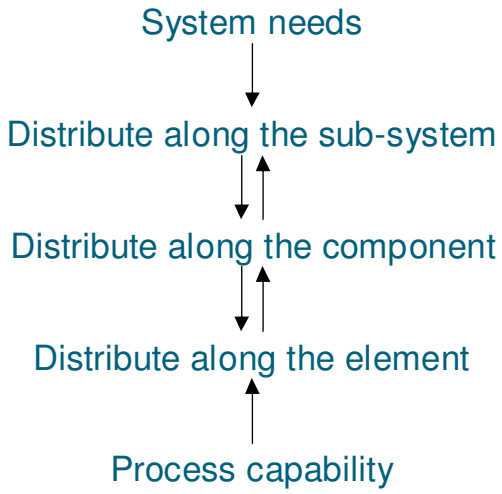
Functional Tolerancing & Worstcasing

1. OBJECTIVE
2. WORSTCASING AND CAPACITY ANALYSIS
3. FUNCTIONAL DESIGN AND FUNCTIONAL TOLERANCING
4. WORST-CASE ANALYSIS
5. EXAMPLES OF APPLICATIONS

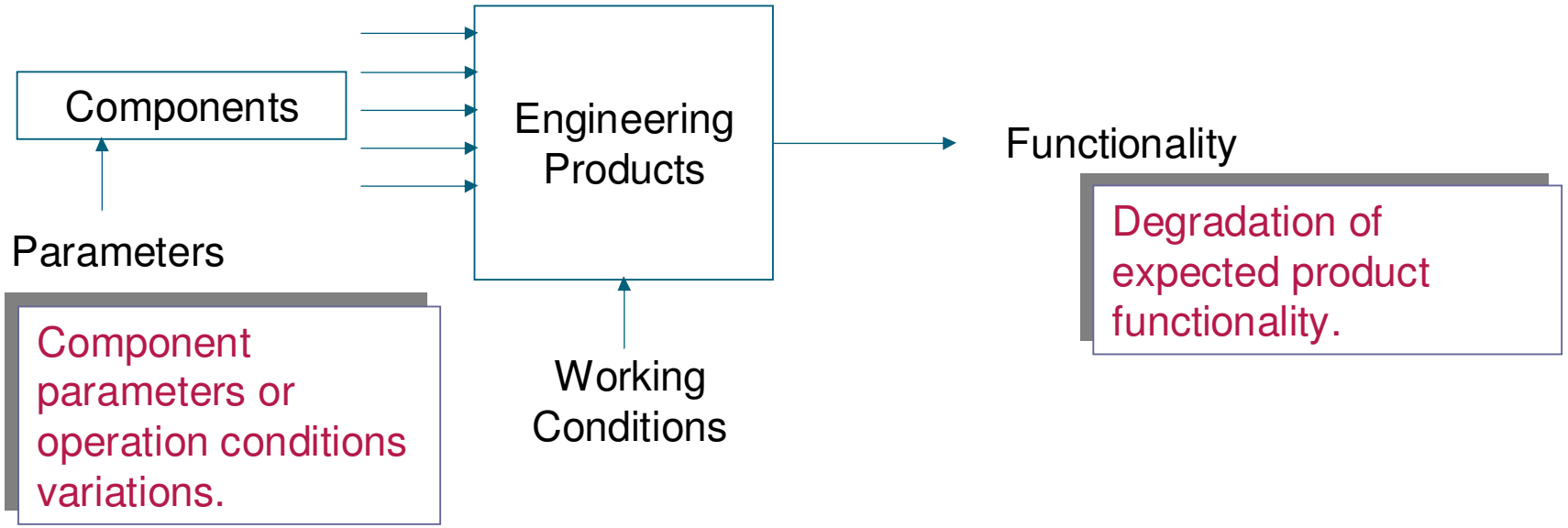
Objectives of Functional Design & Worst-Casing Process

- Predict product functionality during first design stages before investing in equipments, tools, etc.
- Identify critical tolerances that need to be tightened in order to improve quality and those that can be relaxed and thus reduce costs.
- Design products that can be manufactured based on our production capabilities and our suppliers own capabilities.

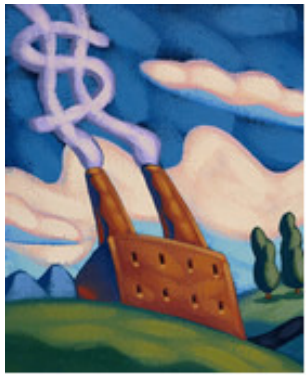




Objective

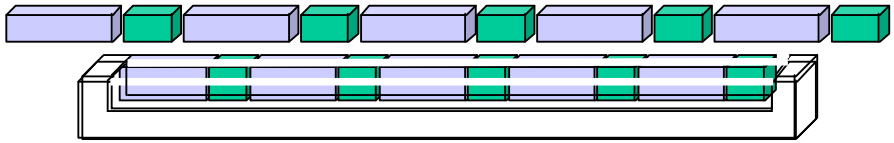


Variations cannot be avoided!



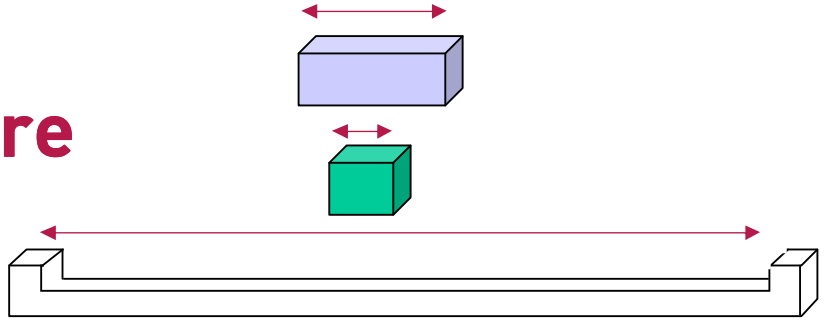
Assure a satisfying operation for the product when conditions vary from the nominal ones.

Example



Gap Specification	0.3 ± 0.3 mm

¿How can we assure Assemblability?



Part 1	10 mm
Part 2	5 mm
Box	75.3 mm

Fine tuning

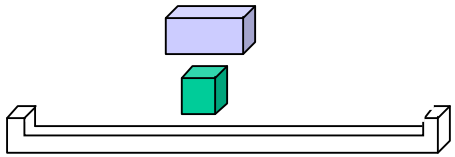
Arithmetical Worst-Case

Statistical Worst-Case

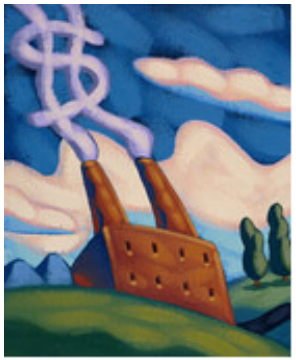
How can we assure Assemblability?

GAP SPECIFICATION 0.3 ± 0.3 mm

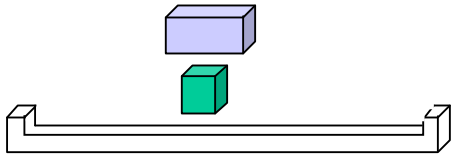
Arithmetic Worst-Case



Part 1 10 ± 0.06 mm
Part 2 5 ± 0.05 mm
Box 75.3 ± 0.10 mm



NOT OK

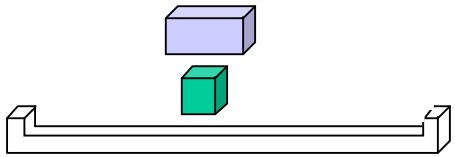


Part 1 10 ± 0.03 mm
Part 2 5 ± 0.02 mm
Box 75.3 ± 0.045 mm

0.3 ± 0.295 mm

OK

Statistic Worst-Case



Part 1 10 ± 0.06 mm
Part 2 5 ± 0.05 mm
Box 75.3 ± 0.10 mm

Statistical control of production

GAP

0.3 ± 0.295 mm

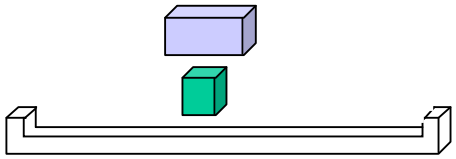
Mean / Deviation

OK

99.9999998%
(centered process)

How?

Statistic Worst-Case



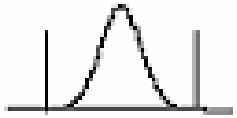
Part 1	**10 ± 0.06 mm**
Part 2	**5 ± 0.05 mm**
Box	**75.3 ± 0.10 mm**

Statistical control of production

GAP

0.3 ± 0.295 mm

Mean / Deviation



OK

99.9999998%

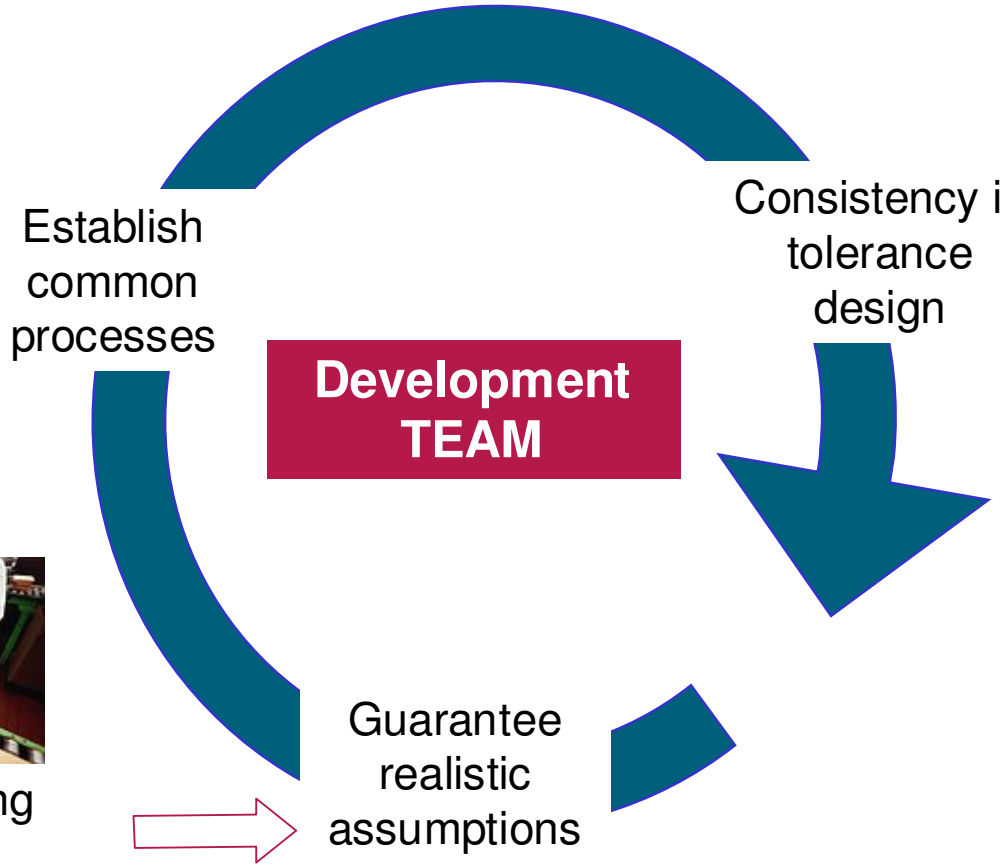
(centered process)

- ✓ Consider the impact of the expected variation of each parameter *(part length)* on the functionality of the product *(gap)*.
- ✓ Simulate the product functionality capability before first samples are available.

Functional Design & Worst-Casing Process Objectives

- ✓ Ensure product quality and reliability by means of the analysis of the manufacturing process during the first product design stages.

Manufacturing Process



Functional Design & Worst-Casing Process Objectives

✓ Ensure the link between part specification and part functionality.

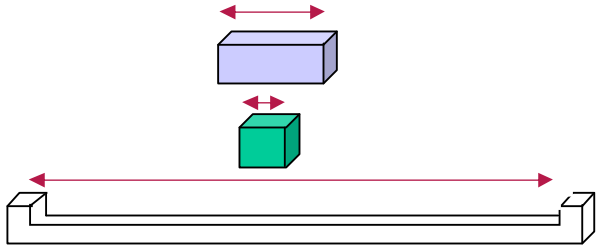
Part is in specs

But the system does not work!

This situation creates confusion between the engineering community (product & process engineers) and suppliers base...

Functional Design & Worst-Casing Process Objectives

- ✓ Define a process that guarantees a consistency through the entire worst-casing process, in particular considering realistic manufacturing process capability data during first product design phases.



Part 1 **10 ± 0.06 mm. Cpk = 1.33**

Part 2 **5 ± 0.05 mm. Cpk = 1.33**

Box **75.3 ± 0.10 mm. Cpk = 1.33**

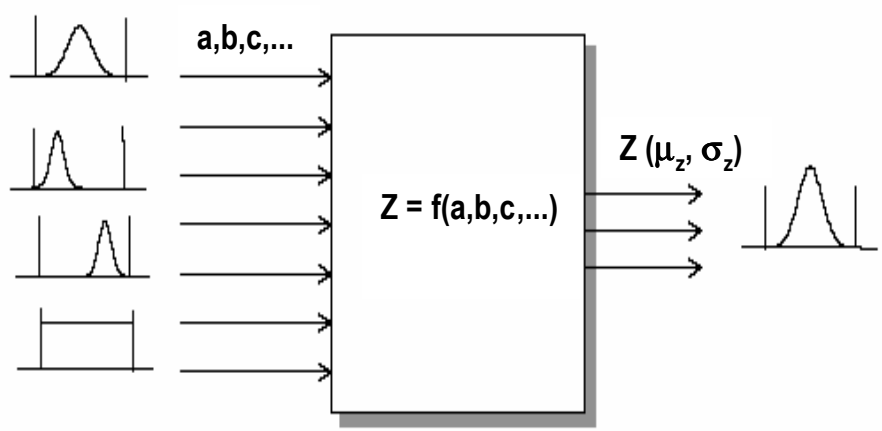
Component/part characteristics deviations from the assumptions made in the worstcasing ...

Will them significantly affect final product quality?

Worstcasing & capability assessment

Worst-Case: simulate real manufacturing process capability, in order to optimise tolerances stack-up and assure that the expected product functionality stays within the intended range, without the need to reduce the tolerances in excess, and thus reducing the final part cost impact.

Manufacturing process assumptions
(injection tolerances, assembly tolerances, etc)



Variation of Functional parameter Z (defined at system level)
as a function of component's variability.

Critical Dimensions
Functional Critical Dimension (FCD)

Z: Transfer Function
Critical Product Performance Parameter (CPPP)

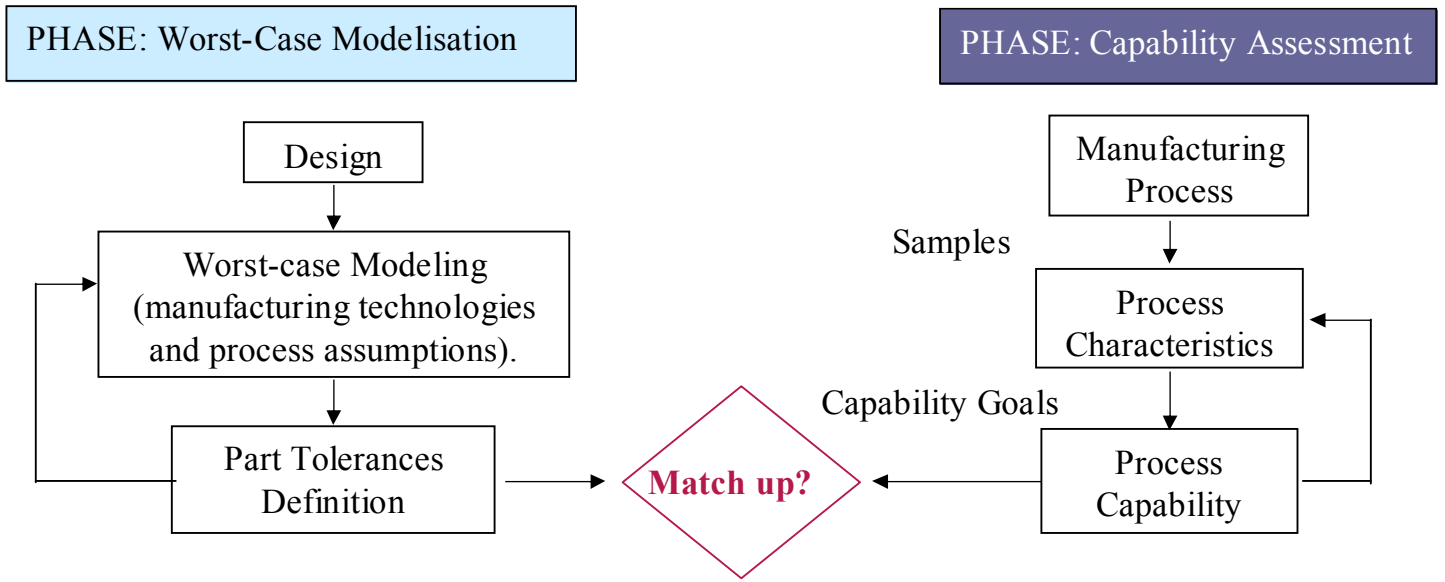
Geometrical Tolerances Stack-up **&** **Other product functionality critical parameters**

Worstcasing & capability assessment

- ✓ Optimise tolerances definition.
- ✓ Control product functional parameters consistency.
- ✓ Establish a criteria for assessing manufacturing processes capability for the final tooled parts.
- ✓ Guarantee that assumptions made in the design about the manufacturing process are realistic.
- ✓ Guarantee consistency of product quality and functionality.

Definitions

- **Capability Indexes (Cp, Cpk, Biass).**
- **Objectives for capability indexes at design and product qualification stages.**
- **Capability statistical confidence level.**



Arithmetical Worst-Case

Worstcasing where the parts dimensions or parameters are assumed to be located at the maximum or at the minimum of their tolerance range and that all errors have the same direction.

It is the most "***primitive***" of the worstcasing methods and also is the ***safer*** one but produces very tight tolerances, that might be too ***expensive*** or impractical to manufacture.

Statistical Worst-case

Worstcasing where the parts functional critical dimensions are assumed to be distributed statistically. A random variation of the dimensions rarely causes that all parts are simultaneously at their extreme values and all in the same direction. The variation of one parameter can partially cancel the variation of another parameter.