# How to sell technology

## - success and failure stories -

I) Uncertainty in Measurement of CMM's 1978-1981

II) volumetric error compensation for commercially available CMM's 1981

III) Gear measurement on CMM's without Rotary Stage 1982

IV) Feature Based Measurement for CMM's 1991

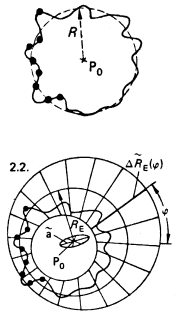
V) New Standard I++ (use CMM Software which fit's your needs) since 2002

VI) Using of strategy generators for sensor path generation



## I) Uncertainty in Measurement of CMM's 1978-1981 (1)

**Publication in VDI-Z 1978**




Example: Is Circle center in tolerance?

Nominal

X0= 0.000 +/- 0.025 (mm) y0= 0.000 +/- 0.015 (mm)

Confidence level 95%

Actual (9 points)

X0= -0.012 +/- 0.027 (mm) y0= 0.006 +/- 0.008 (mm)

Confidence level 85% -> add 6 points (Automatic calculated)

Actual (15 points)

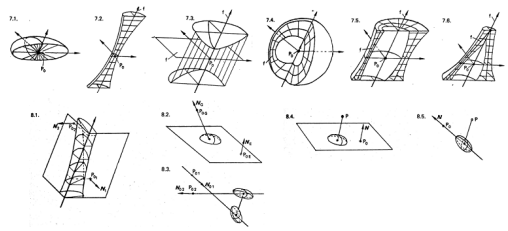
X0= -0.010 +/- 0.015 (mm) y0= 0.005 +/- 0.005 (mm)

Confidence level 96%



## I) Uncertainty in Measurement of CMM's 1978-1981 (2)

Uncertainty areas for prismatic elements and intersections



Advantage: measuring accuracy based on number and distribution of measured points



## I) Uncertainty in Measurement of CMM's 1978-1981 (3)

What happened:

Result of discussions with Industry until 1981

- Method cannot be used

- Reason: Too difficult to train QC personal with mechanical Engineering background

- No change until Today (2007)

Related Developments until Today:

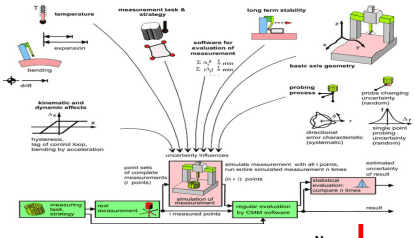
Since 1990 :„Guide to the Expression of Uncertainty in Measurement (GUM)“

Since 2003 :„Virtual CMM“ in practical use



## I) Uncertainty in Measurement of CMM's - future (4)

Virtual CMM (introduced by PTB)



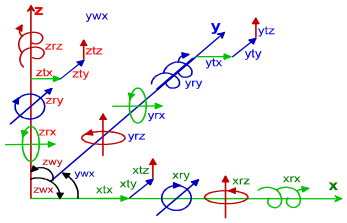

New

| Step | Feature | | Nominal | +Tol | -Tol | Actual | Deviation | Uncertainty | | Status | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | D1 | ⌀ | 2,450 | 2,470 | 2,430 | 2,446 | -0,004 | +/- 0,006 | | OK | |
| 2 | W1 | ↔ | 6,600 | 6,605 | 6,595 | 6,621 | 0,021 | +/- 0,021 | | | OUT |



## II) Volumetric error compensation for commercially available CMM's (1)

1981 Leitz introduced the worlds first full 3D software error compensation for CMM's




Parametric Errors of a Three Cartesian Axis Machine

Advantage: Higher accuracy, less cost , can be recalibrated in the field

## II) Volumetric error compensation for commercially available CMM's (2)

**What happened:**

For several years since 1981, many metrology managers in industry did not buy „software error compensation“, they asked for „mechanical accuracy“

In 1984 ZEISS (supported by PTB) introduced their own error compensation under the name

CAA – „Computer Assisted Accuracy“

This name sounded more positive than „Software Error Compensation“,

and got used by the whole industry since than

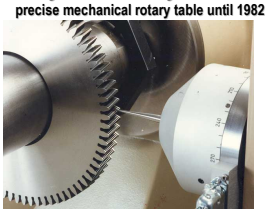
**Today** : Software Compensation of remaining mechanical errors is a standard



## III) Gear measurement on CMM's without Rotary Stage 1982 (1)

**Traditionally** : Gears are measured on a precise mechanical rotary table

On high accurate CMM's gears are also exclusively measured with an additional precise mechanical rotary table until 1982



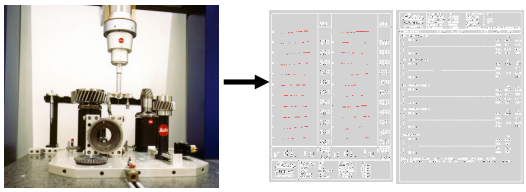
**Advantage**: accurate measurement

**Disadvantage**: only one gear can be measured in one setup (without loading mechanism) – especially for CMM's



## III) Gear measurement on CMM's without Rotary Stage 1982 (2)

In 1985 Gear measurement **without rotary table** was introduced on high accurate CMM's



**Advantage**: - no additional precise rotary – lower cost (about 60.000 Euro)

- many gears in one setup on a machine – less operator intervention



## III) Gear measurement on CMM's without Rotary Stage 1982 (3)

**What happened** ?:

- total cost reduction – not including handling advantages – 20%

- In spite of this :for about 2 to 3 years ALL leading Car Companies bought the more expensive solution with rotary

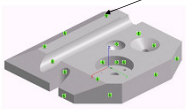
Reason: QC personal used to measure Gears exclusivly on rotary stages

**Today** : this is an accepted Gear measurering methodes



## IV) Feature based Measurement for CMM‘s 1991 (1)

Until 1991 CMM part routines could only run ALL features programmed



| Feature | | Nominal | U-Tol | L-Tol |
|---|---|---|---|---|
| Step 7 | Pos.: 001 | | | |
| Diameter | mm | 85.05000 | 0.05000 | -0.05000 |
| Step 18 | Pos.: 002 | | | |
| Diameter | mm | 8.90000 | 0.10000 | -0.10000 |
| B Location | mm | 47.00000 | 0.05000 | -0.05000 |
| A Location | dd | 60.00000 | 0.05000 | -0.05000 |
| Step 22 | Pos.: 003 | | | |
| Diameter | mm | 8.90000 | 0.10000 | -0.10000 |
| B Location | mm | 47.00000 | 0.05000 | -0.05000 |
| A Location | dd | 90.00000 | 0.05000 | -0.05000 |
| Step 26 | Pos.: 004 | | | |
| Diameter | mm | 8.90000 | 0.10000 | -0.10000 |
| B Location | mm | 47.00000 | 0.05000 | -0.05000 |
| A Location | dd | 120.00000 | 0.05000 | -0.05000 |
| Step 30 | Pos.: 005 | | | |
| Diameter | mm | 8.90000 | 0.10000 | -0.10000 |
| B Location | mm | 47.00000 | 0.05000 | -0.05000 |
| A Location | dd | 150.00000 | 0.05000 | -0.05000 |
| Step 34 | Pos.: 006 | | | |
| Diameter | mm | 8.90000 | 0.10000 | -0.10000 |
| B Location | mm | 47.00000 | 0.05000 | -0.05000 |
| A Location | dd | 180.00000 | 0.05000 | -0.05000 |
| Step 38 | Pos.: 007 | | | |
| Diameter | mm | 8.90000 | 0.10000 | -0.10000 |
| B Location | mm | 47.00000 | 0.05000 | -0.05000 |
| A Location | dd | 210.00000 | 0.05000 | -0.05000 |
| Step 42 | Pos.: 008 | | | |
| Diameter | mm | 8.90000 | 0.10000 | -0.10000 |
| B Location | mm | 47.00000 | 0.05000 | -0.05000 |
| A Location | dd | 240.00000 | 0.05000 | -0.05000 |

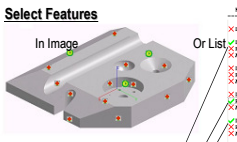
Programming cost high, no flexibility, not suitable for shop floor



## IV) Feature based Measurement for CMM‘s 1991 (2)

In 1991 BOSCH requested ALL features to be measured are selectable at runtime

**Select Features**




| Feature | | Nominal | U-Tol | L-Tol |
|---|---|---|---|---|
| Step 7 | Pos.: 001 | | | |
| Step 42 | | 85.05000 | 0.05000 | -0.05000 |
| Step 18 | Pos.: 002 | | | |
| Diameter | mm | 8.90000 | 0.10000 | -0.10000 |
| B Location | mm | 47.00000 | 0.05000 | -0.05000 |
| A Location | dd | 60.00000 | 0.05000 | -0.05000 |
| Step 22 | Pos.: 003 | | | |
| Diameter | mm | 8.90000 | 0.10000 | -0.10000 |
| B Location | mm | 47.00000 | 0.05000 | -0.05000 |
| A Location | dd | 90.00000 | 0.05000 | -0.05000 |
| Step 26 | Pos.: 004 | | | |
| Diameter | mm | 8.90000 | 0.10000 | -0.10000 |
| B Location | mm | 47.00000 | 0.05000 | -0.05000 |
| A Location | dd | 120.00000 | 0.05000 | -0.05000 |
| Step 30 | Pos.: 005 | | | |
| Diameter | mm | 8.90000 | 0.10000 | -0.10000 |
| B Location | mm | 47.00000 | 0.05000 | -0.05000 |
| A Location | dd | 150.00000 | 0.05000 | -0.05000 |
| Step 34 | Pos.: 006 | | | |
| Diameter | mm | 8.90000 | 0.10000 | -0.10000 |
| B Location | mm | 47.00000 | 0.05000 | -0.05000 |
| A Location | dd | 180.00000 | 0.05000 | -0.05000 |
| Step 38 | Pos.: 007 | | | |
| Diameter | mm | 8.90000 | 0.10000 | -0.10000 |
| B Location | mm | 47.00000 | 0.05000 | -0.05000 |
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| Step 42 | Pos.: 008 | | | |
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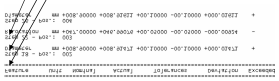
| B Location | mm | 47.00000 | 0.05000 | -0.05000 |
| A Location | dd | 240.00000 | 0.05000 | -0.05000 |

**Select Features Protocol**



## IV) Feature based Measurement for CMM's 1991 (3)

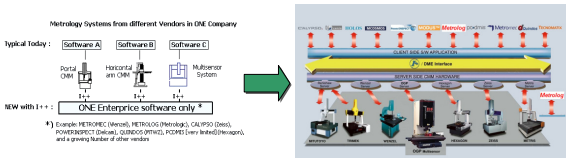
Advantage: - No programming
- No Metrology knowledge needed
- just select and measure
- ideal for shop floor measurement

What happened: Was immedeatly accepted in Industry
Reason: No Training, No special knowledge

Today: Standard in CMM software



## V) New Standard I++ : use CMM Software which fit's your needs(1)



Advantage: - user selects software and systems independent
- higher performance
- less people



## V) New Standard I++ : use CMM Software which fit's your needs(2)

What is happening since 2002 ?:

- technical capability of the concept is demonstrated and proven on many exhibitions
- it is in the interest of major customers and strongly pushed by these customers
- It can save a LOT OF MONEY for Companies using I++

- In spite of this : There are very few real installations so far

Reason: It needs a STRONG MANAGEMENT to move from MANY DIFFERENT existing SOFTWARE packages in a company to ONE COMMON SOFTWARE

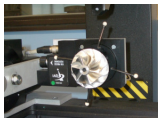
Future: the implementations will slowly grow



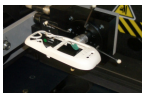
## VI) Using of strategy generators (Sensor movement automatically created by CAD and measuring task)

Especially Required for line and area sensors - Timeframe until 2015-2020

Impeller



Cell Phone cover



Turbine blade

Problems in implementation : unknown yet

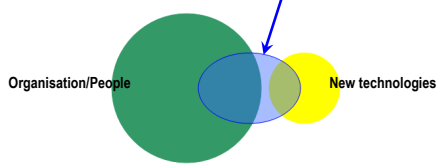


## How to sell technology

### Conclusion: Reasons for success and failure

| Mayor holding block | Saves money for user | Easy to understood | Easy to implement in Organisation | Fit's past experience | No Training required |
|---|---|---|---|---|---|
| I) Uncertainty in Measurement of CMM's | Yes | No | No | No | No |
| II) Volumetric error compensation for CMM's | Yes | No | | No | |
| III) Gear measurement without Rotary Stage | Yes | Yes | No | No | Yes |
| IV) Feature Based Measurement for CMM's | Yes | Yes | Yes | Yes | Yes |
| V) I++ (use Software which fit's your needs) | Yes | Yes | No | No | No |
| Future → VI) Using strategy generators | Yes | ? | ? | ? | ? |



## How to sell technology

### Consequence: consultancy required to support organisations and people when integrating new technologies