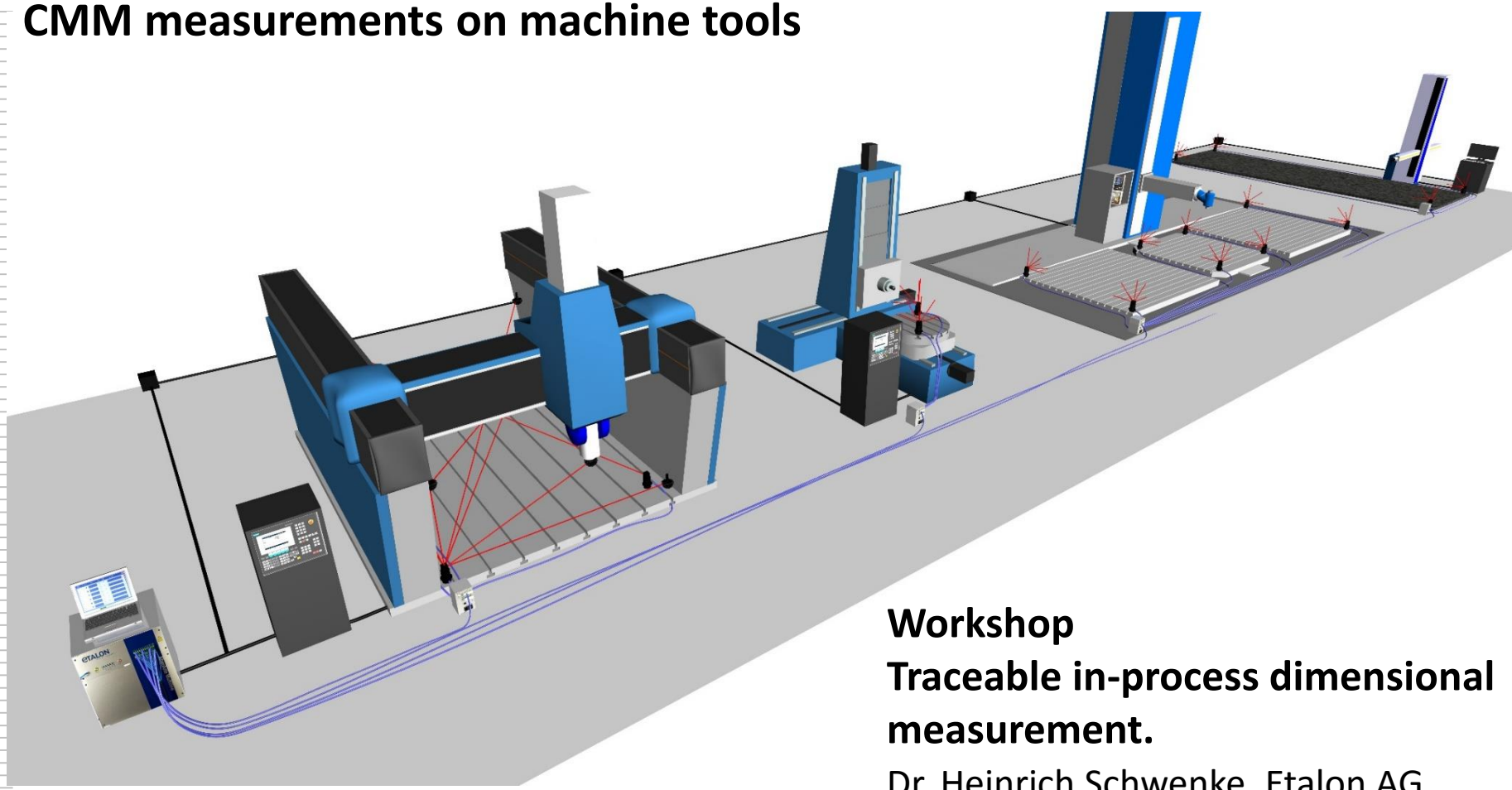
Large parts with critical tolerances:

Concepts and possible solutions for traceable CMM measurements on machine tools



Workshop
Traceable in-process dimensional measurement.

Dr. Heinrich Schwenke, Etalon AG

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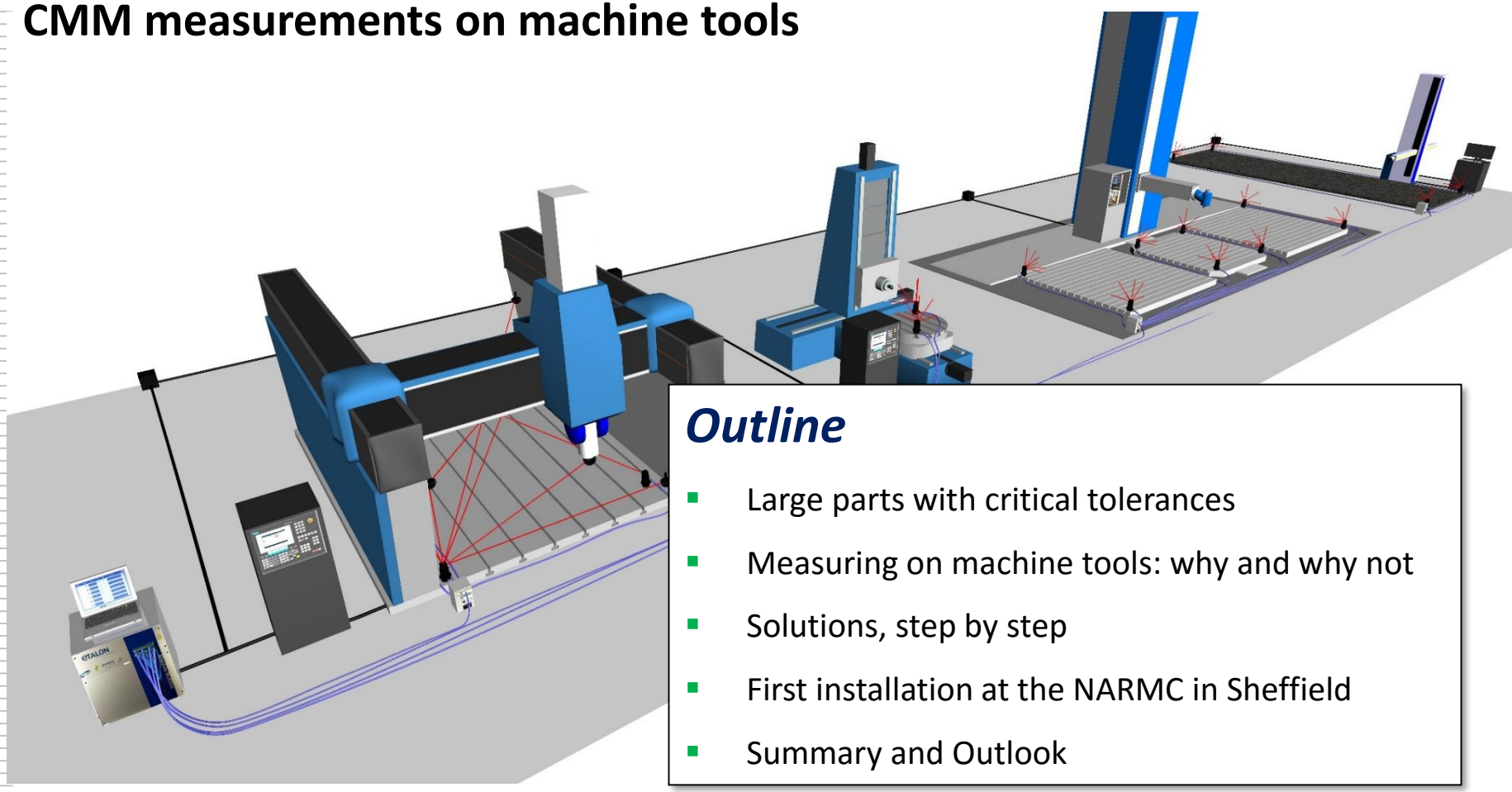
Concepts and possible solutions for traceable CMM measurements on machine tools

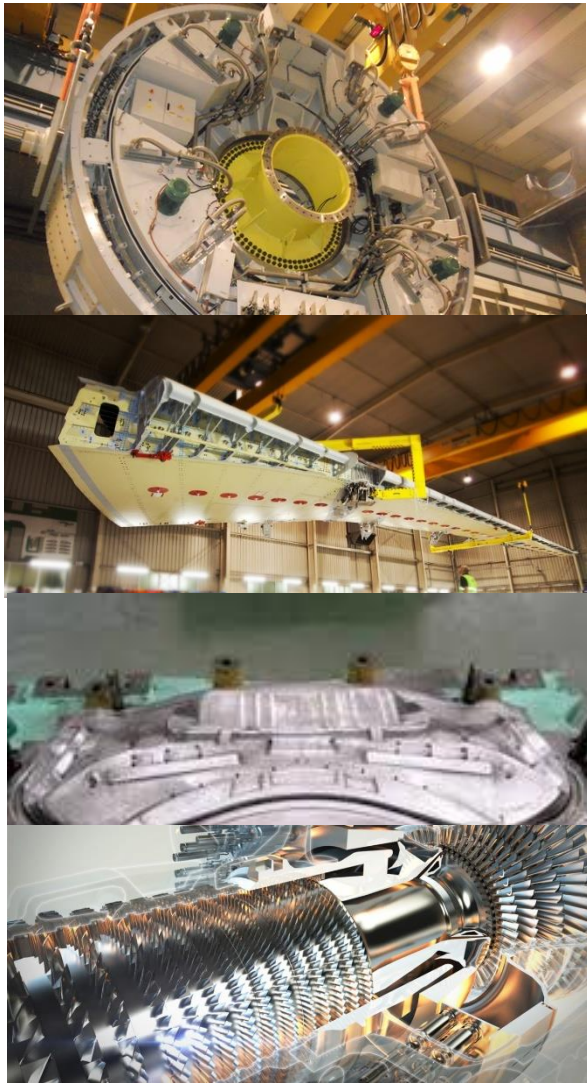


Outline

- Large parts with critical tolerances
- Measuring on machine tools: why and why not
- Solutions, step by step
- First installation at the NARMC in Sheffield
- Summary and Outlook

Where to find critical tolerances on large parts ?

- Gas and steam turbine manufacturing
- Wind power components, especially gearboxes, gears and other transmission components
- Tool and die production for body in white
- Aerospace turbines
- Aerospace structural parts (wings up to 35 m)
- Large optics
- Special applications: Vacuum vessels, scientific components like magnet coils



Inspection of parts on the machine tool

Why?
▪ No CMM needed
▪ Clamping / unclamping can be avoided
▪ Transportation can be avoided
▪ Direct production feedback loop can be closed

→ **Cost savings**

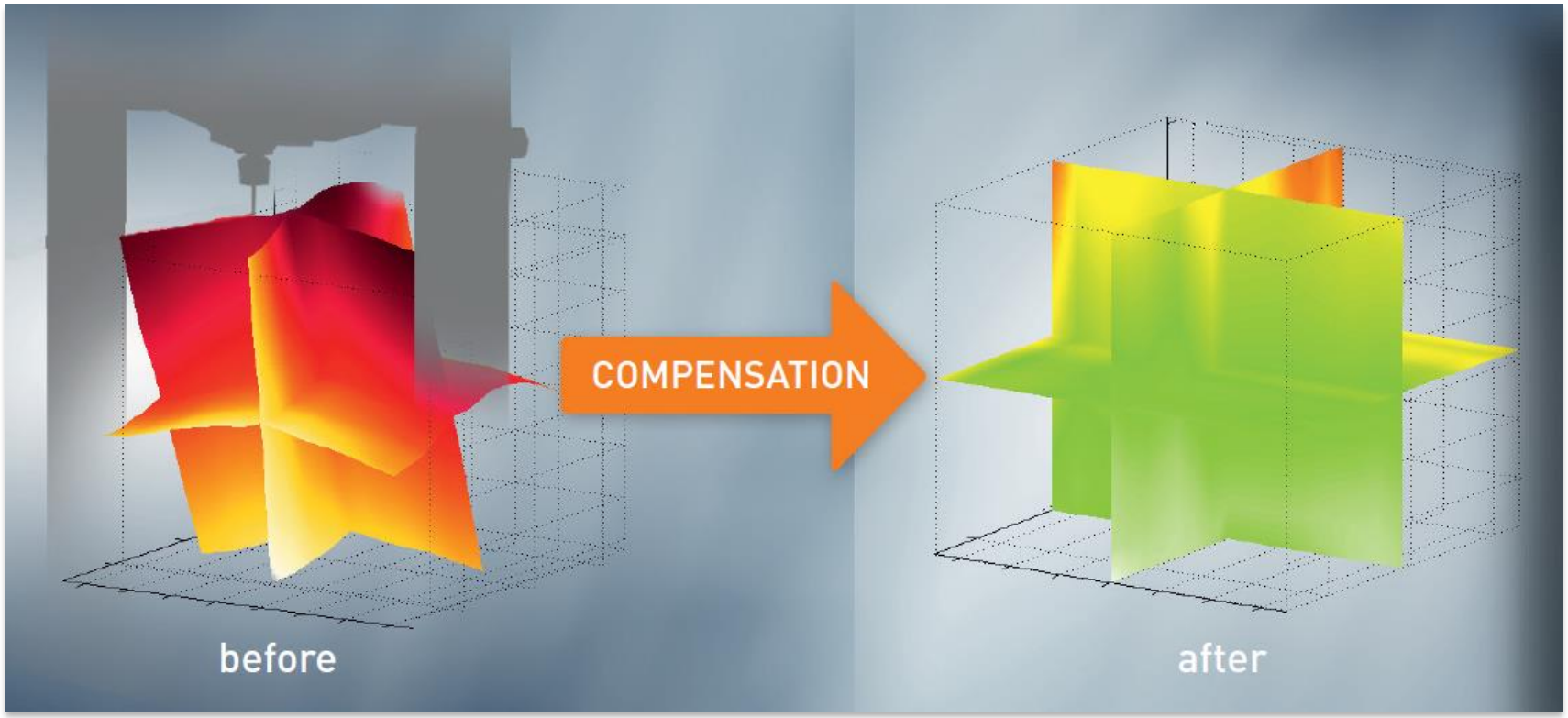
Inspection of parts on the machine tool

Why not?
Machine tool time more expensive than CMM time
Machine accuracy insufficient
Measurement not traceable
No supporting standards
Metrology software insufficient or incompatible
Environmental conditions bad / changing

-> Addressing these issues especially for manufacturing of large parts

Problem		Solution
Machine tool time more expensive than CMM time		None, depending on part / process
Machine accuracy insufficient		**Volumetric calibration**
Measurement not traceable		
No supporting standards		
Metrology software insufficient or incompatible		
Bad environmental conditions		

Concept of volumetric compensation

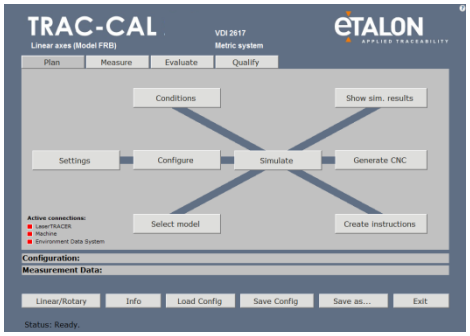


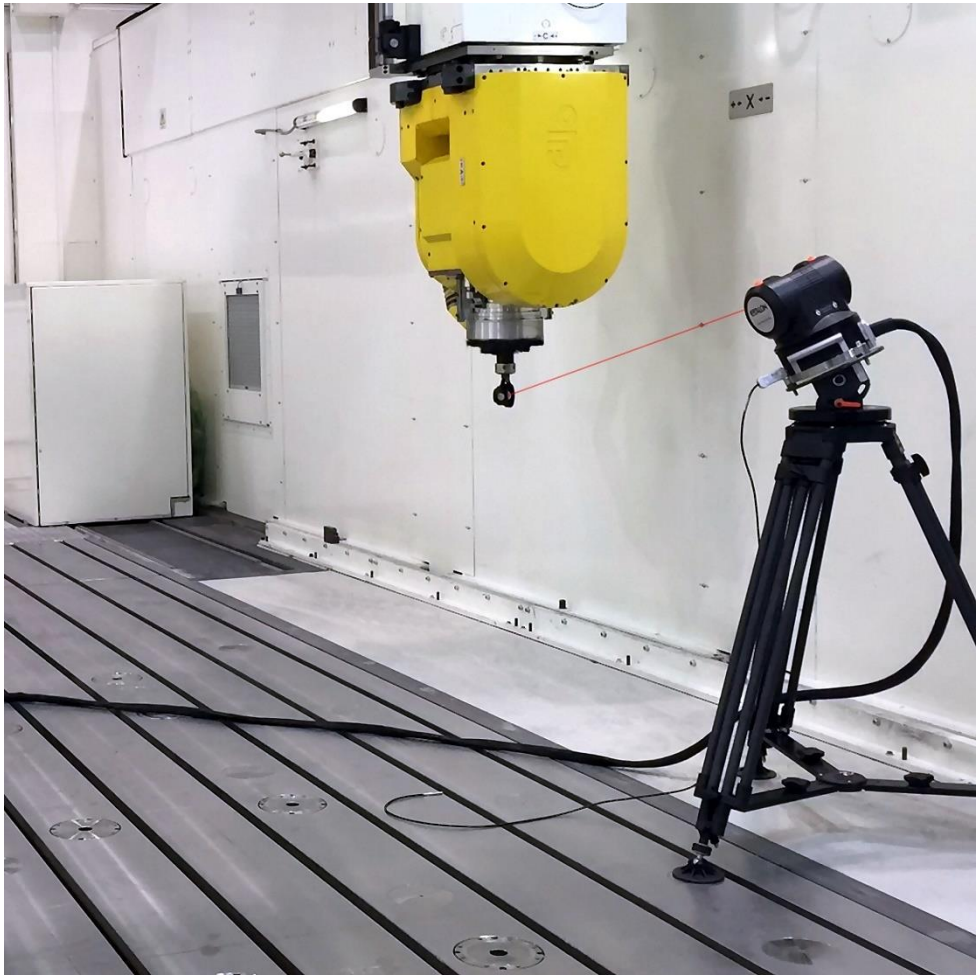
- Measure the geometry errors in the entire machine volume
- Use this information to compensate during machining and measurement

The ETALON solution for volumetric compensation

LaserTRACER-NG

TRAC-CAL
software





Implementation of “volumetric compensation” to machine tool controllers

- **Siemens: “Volumetric Compensation System (VCS)”**
  Lookup tables for all kinematic parameters. Library of kinematic configurations.

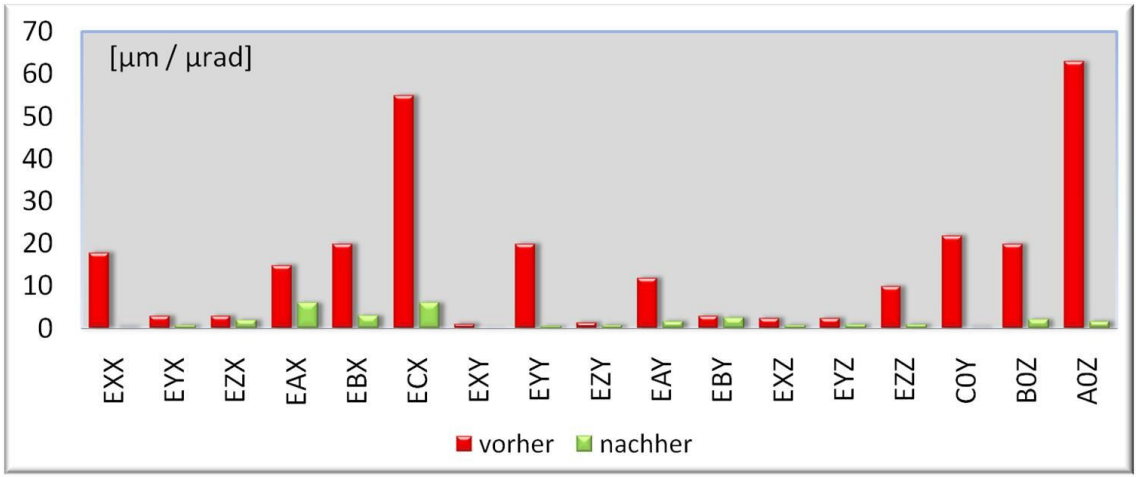
- **Fanuc: “3D-Compensation/3D rotary compensation”**
  Vector field stored in 3D-matrix. 3D rotary also stores rotation vectors

- **Heidenhain: “Kinematics Comp”**
  Configurable lookup tables for linear and rotary axes. Can be configured for arbitrary kinematic setups.

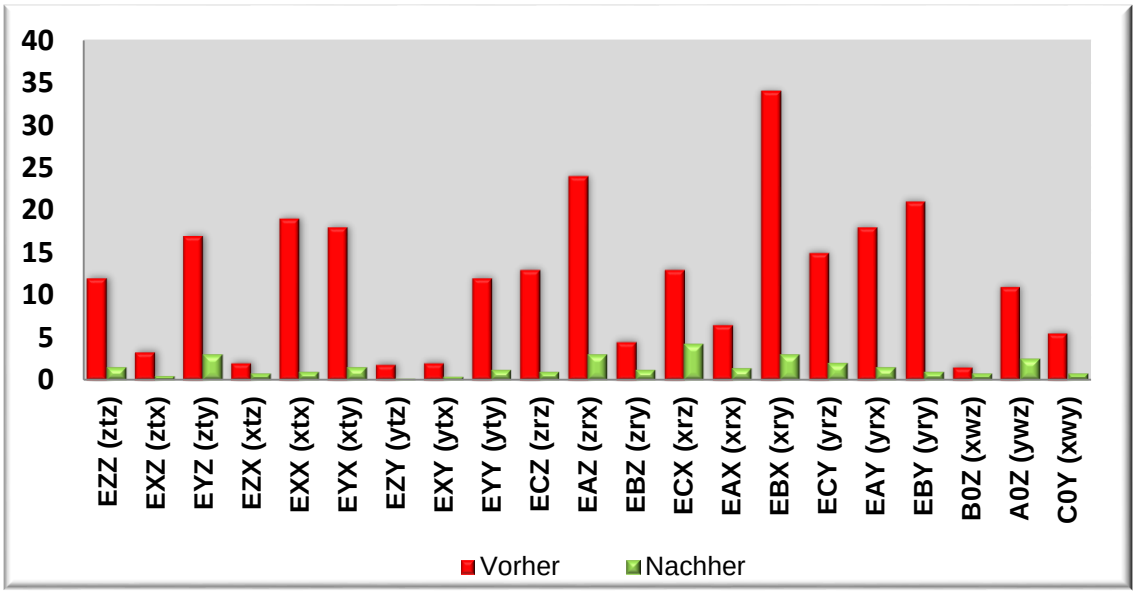
- **Mazak, Fidia, Fagor : Similar to Siemens VCS, less advanced**

Comparision before/after compensation with Siemens 840D

Vertical machining center



Horizontal-machining center



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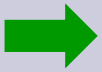
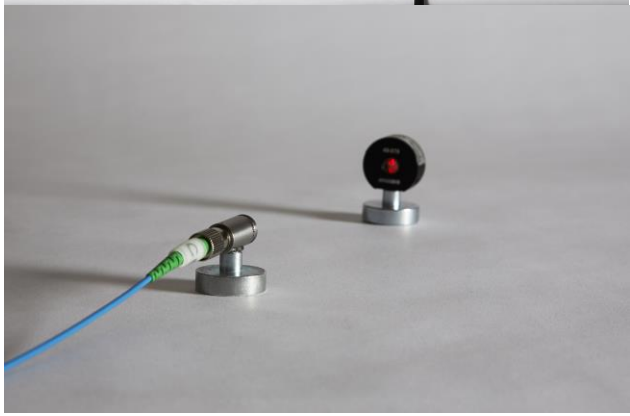
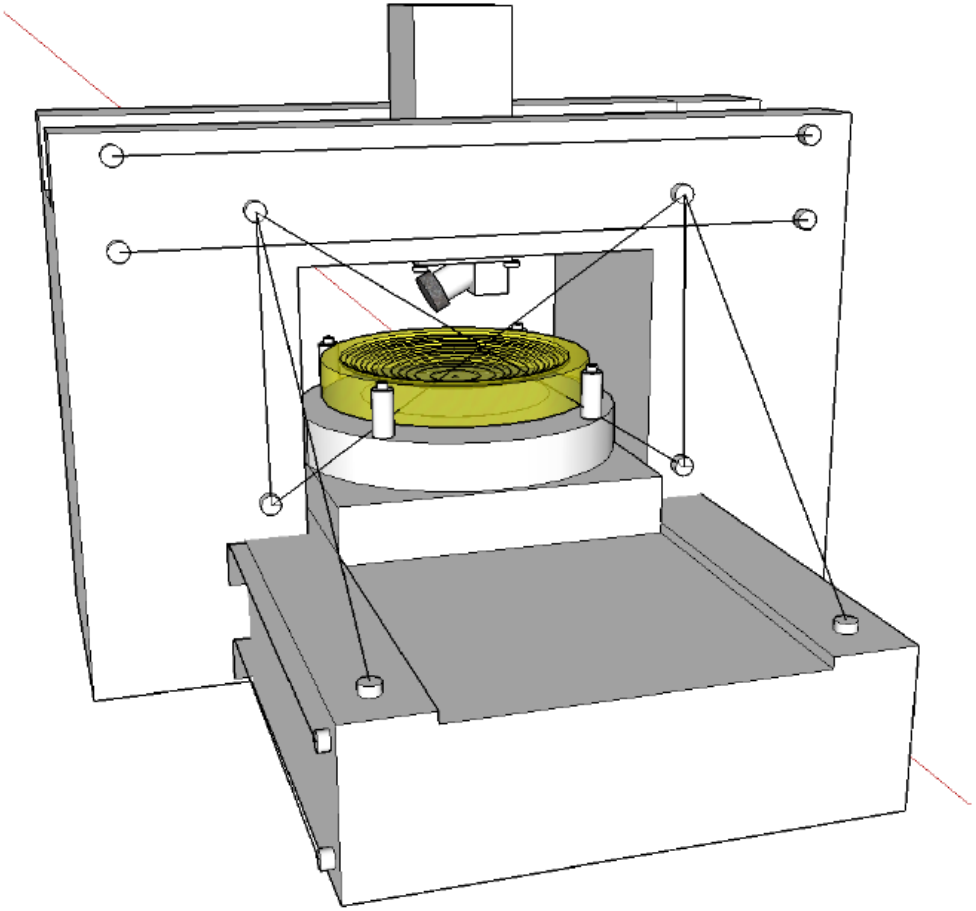
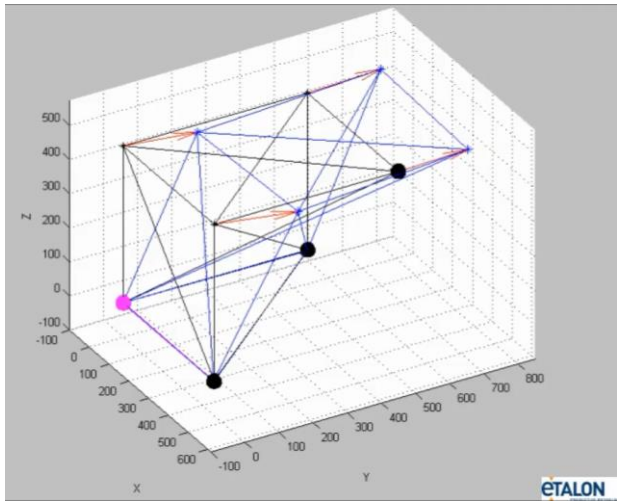
Measurement not traceable		Introducing independent traceable metrology: **Absolute Multiline Technology**
No supporting standards		
Metrology software insufficient or incompatible		
Bad environmental conditions		

Absolute Multiline®-System

- Absolute interferometer
- Central unit with up to 124 synchronous channels
- Measurement uncertainty (95%) : 0.5 µm/m
- Measurement length up to 30 m
- Simple measurement channel consisting only of telecom fiber, collimator and triple reflector (no electrical systems at detector)
- Almost unlimited fiber length possible (several kilometers)
- Eye save infrared radiation
- Metrological traceability by gas absorption cell



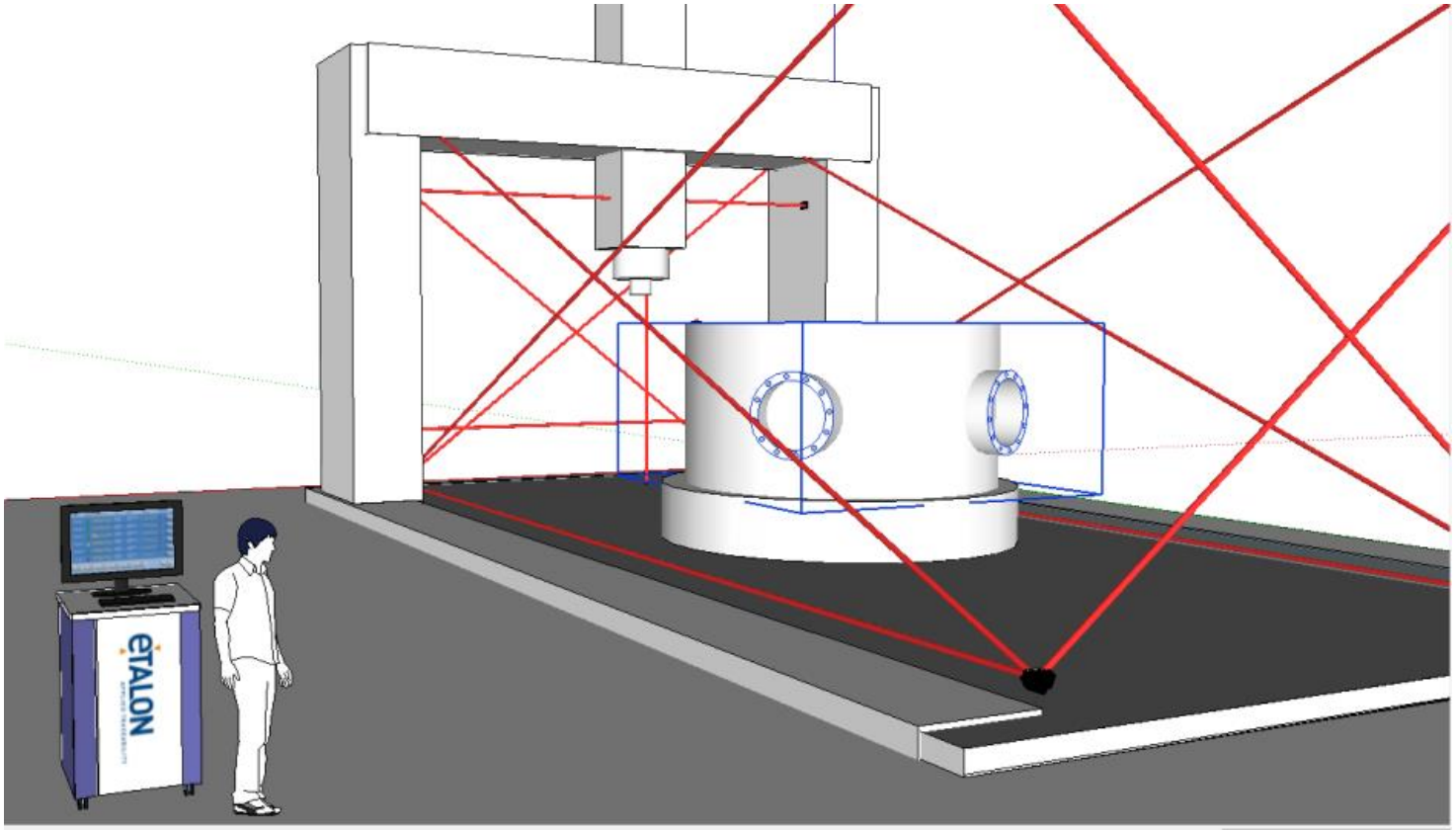




Application example: monitoring of machine deformations

(a) while machine development and testing

(b) constantly integrated in machine structure



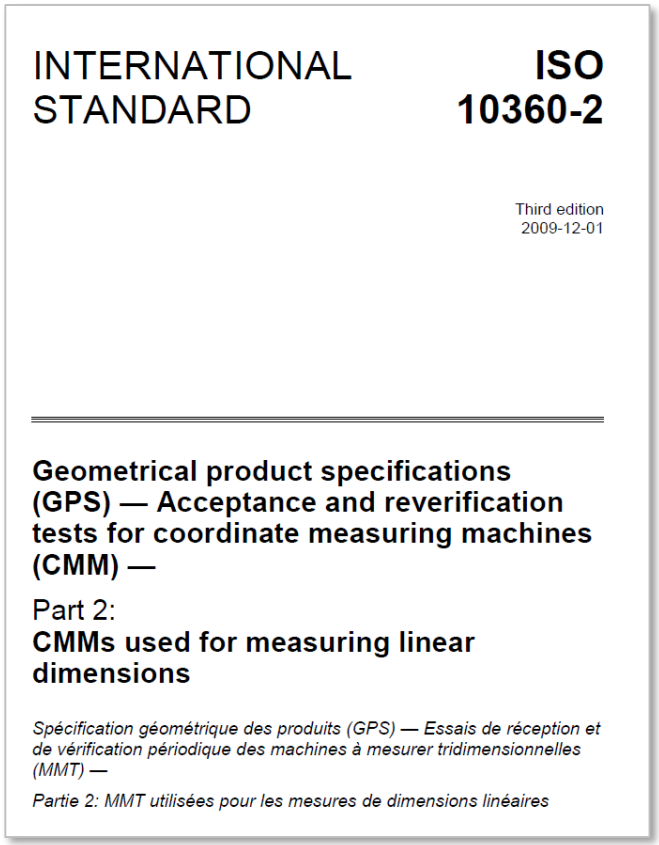
Integration of monitoring lines in the working volume and automated monitoring (and compensation).

Problem		Solution
Machine tool time more expensive than CMM time		None, depending on part / process
Machine accuracy insufficient	→	**Volumetric calibration**
Measurement not traceable	→	Introducing independent traceable metrology: **Absolute Multiline Technology**
No supporting standards	→	**Refering to existing CMM standards**
Metrology software insufficient or incompatible		
Bad environmental conditions		

Applying existing standards

- Follow existing standard procedures used for CMM to assure traceability
- To reflect the special challenges in a production environment: Perform these procedures immediately before the measurement and – if necessary- apply compensations
- The standard procedures are
  - Geometry testing according to ISO 10360-2
  - Probe system testing according to ISO 10360-2/5

➔ The Absolute Multiline System supplies the technology to integrate an independent metrology directly in the measurement volume.



INTERNATIONAL STANDARD **ISO 10360-2**

Third edition
2009-12-01

Geometrical product specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) —

Part 2:
CMMs used for measuring linear dimensions

Spécification géométrique des produits (GPS) — Essais de réception et de vérification périodique des machines à mesurer tridimensionnelles (MMT) —

Partie 2: MMT utilisées pour les mesures de dimensions linéaires

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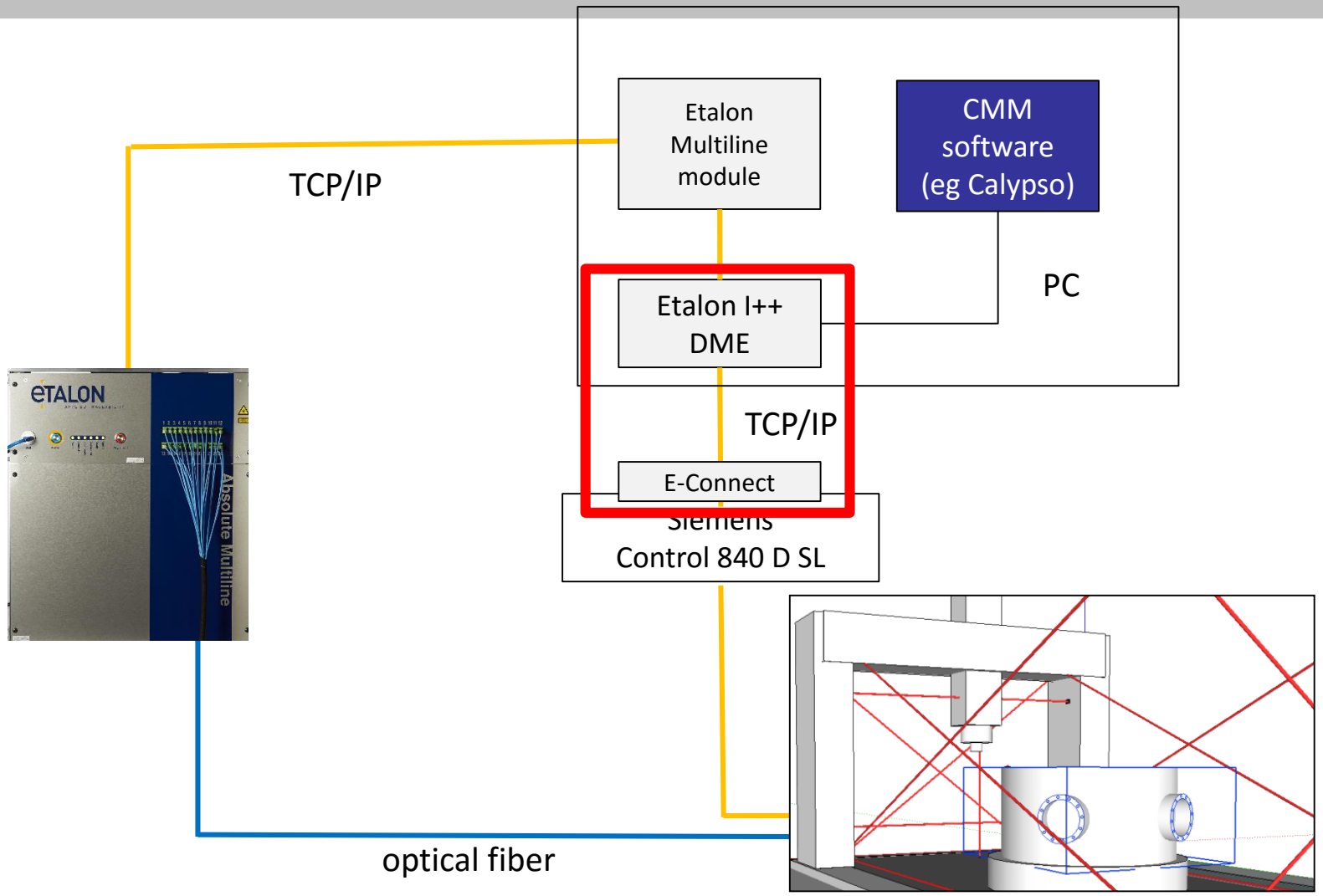
No supporting standards	→	**Refering to existing CMM standards**
Metrology software insufficient or incompatible	→	**Develop Interfaces of CMM software to machine tool controls**
Bad environmental conditions		



I++ serves as interface for Etalon Multiline software and CMM software

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No supporting standards	→	**Refering to existing CMM standards**
Metrology software insufficient or incompatible	→	**Develop Interfaces of CMM software to machine tool controls**
Bad environmental conditions	→	**Temperature monitoring and compensation of machine and workpiece**

Temperature monitoring and compensation concept

Machine:

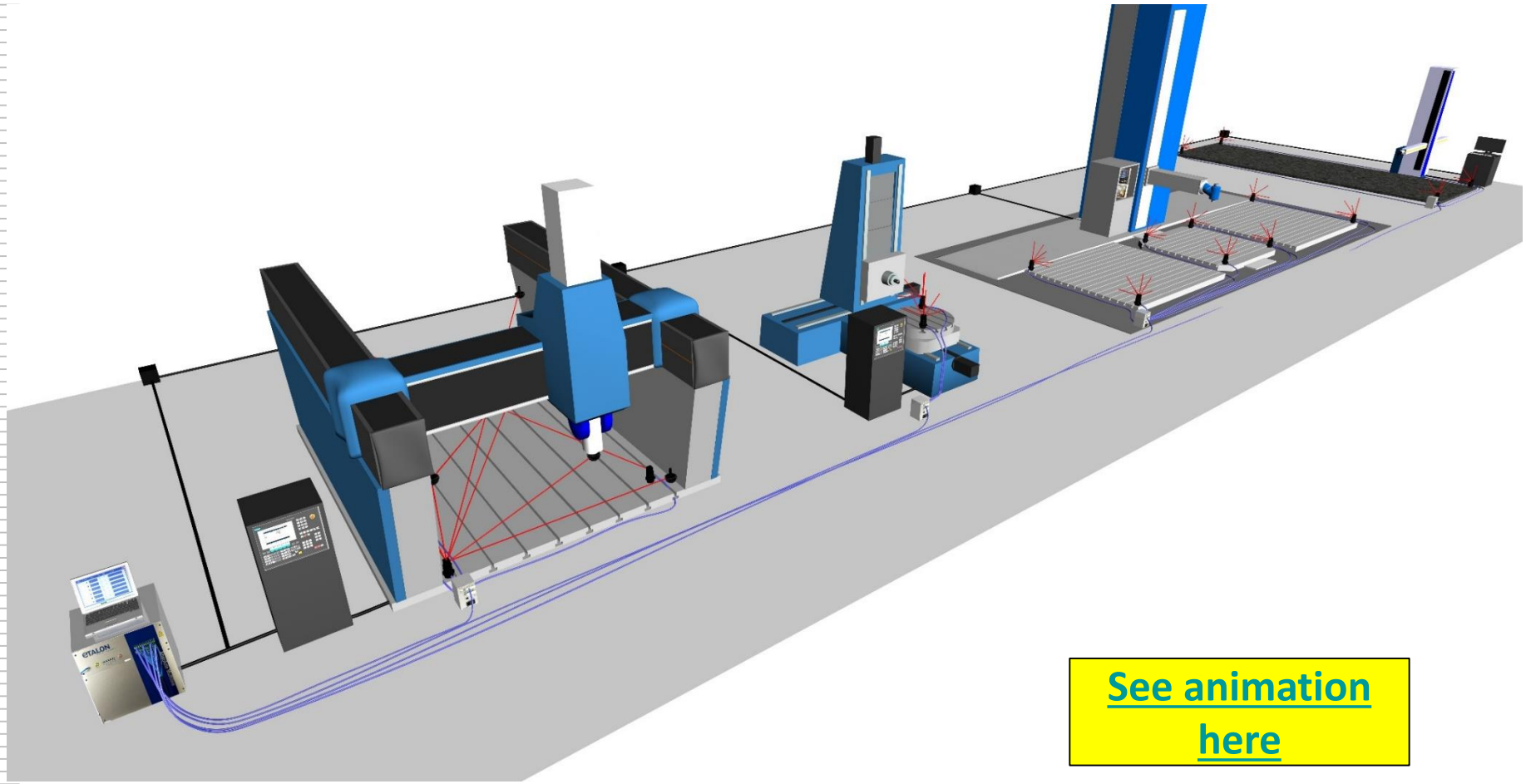
- Machine geometry changes are directly monitored by Absolute Multiline Technology: **no temperature sensors** in machine axes
- Geometry changes on machine are compensated based on Absolute Multiline Technology monitoring procedure

Part:

- Part temperature and temperature distribution is monitored by wireless temperature measurement sensors
- Temperature homogeneity in part checked (< threshold) before measurement and temperature compensation is applied

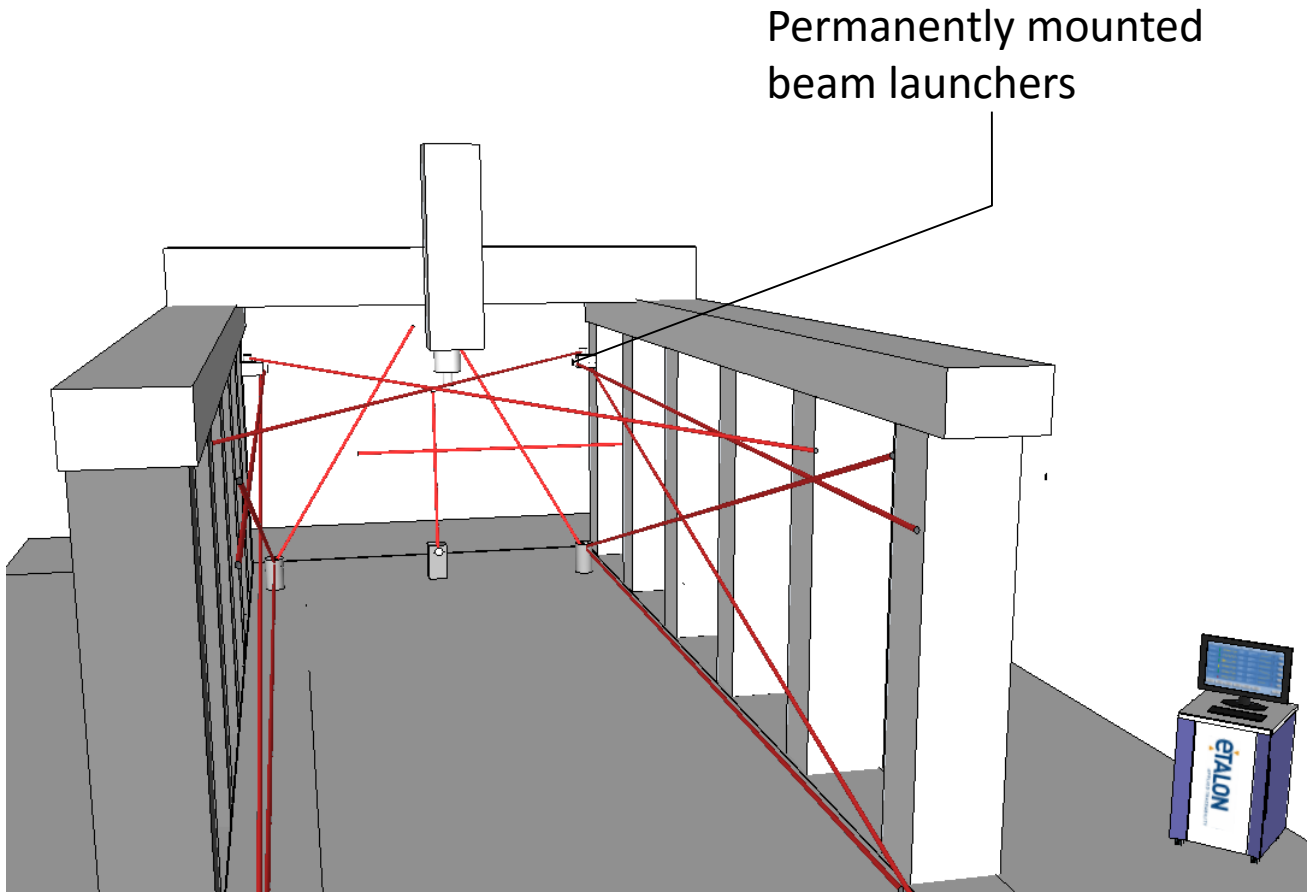
First Installation of concept at the

Nuclear Advanced Manufacturing Research Center (NARMC)



See animation here

Example: Monitoring of a bridge type machine



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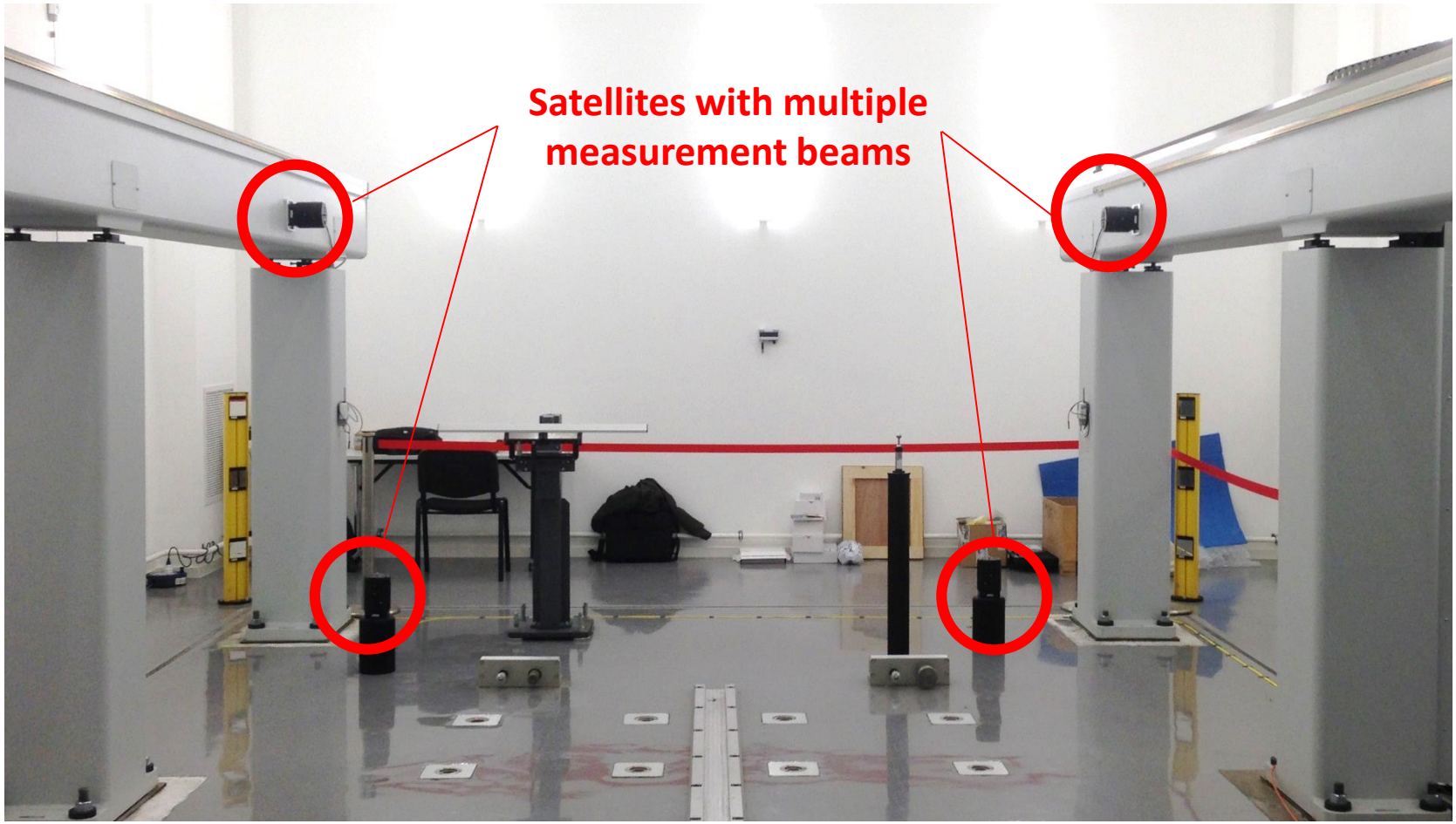

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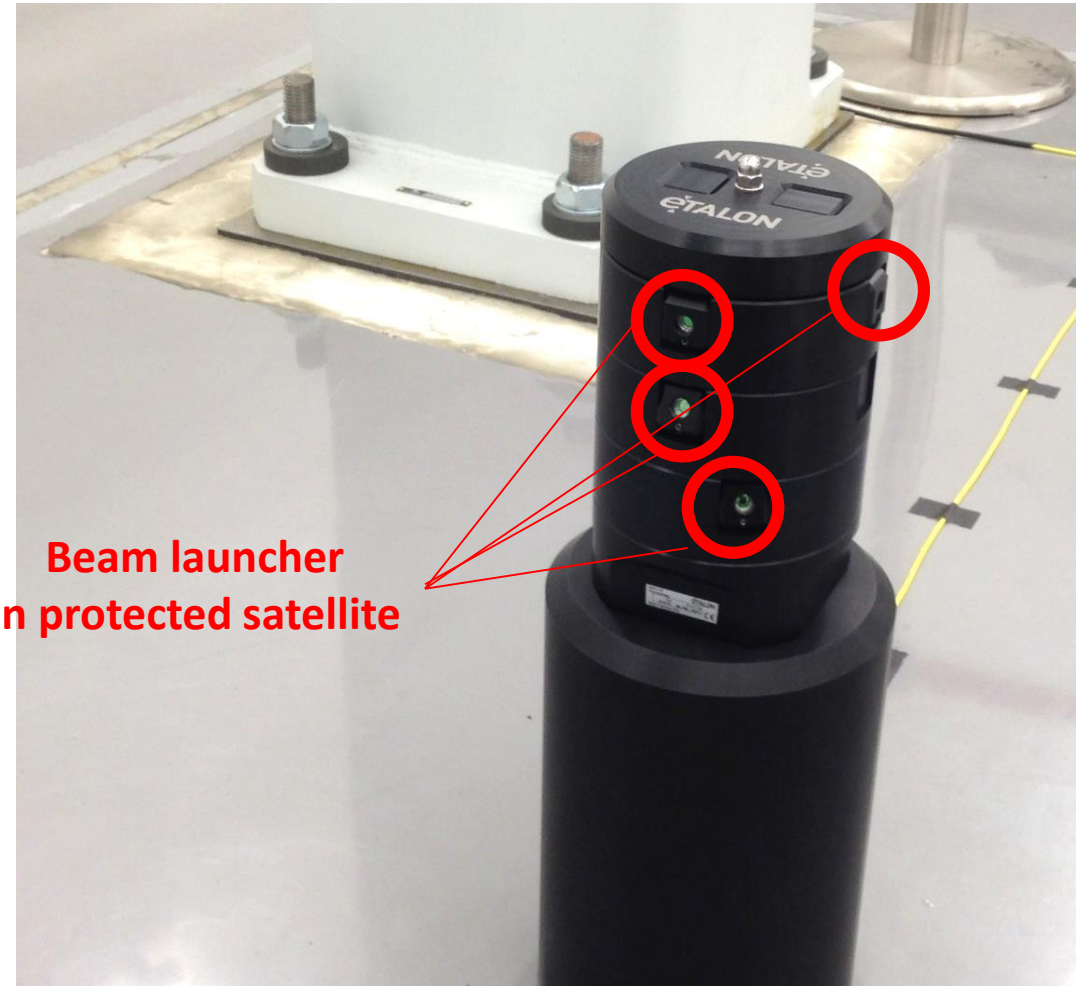
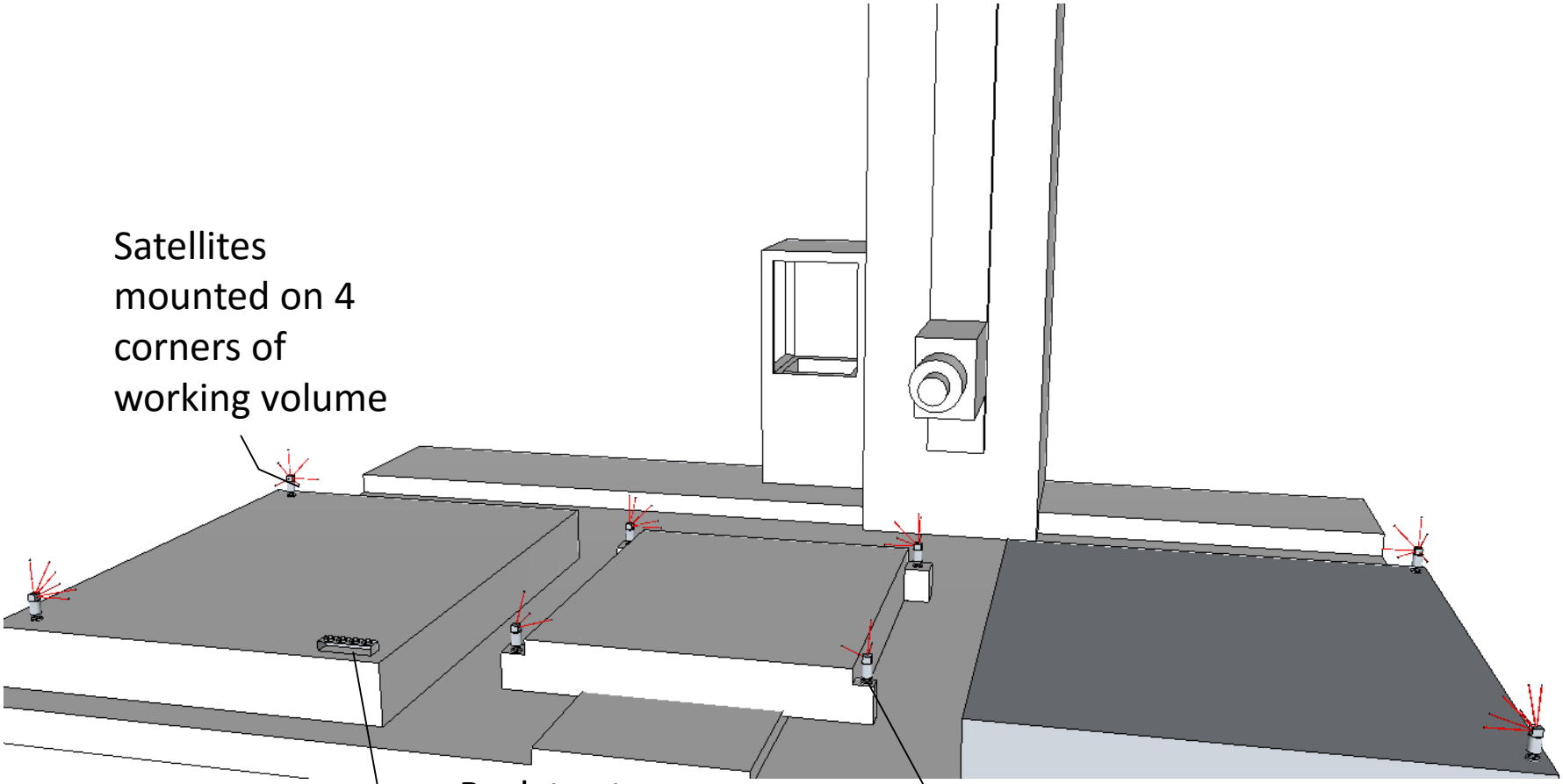
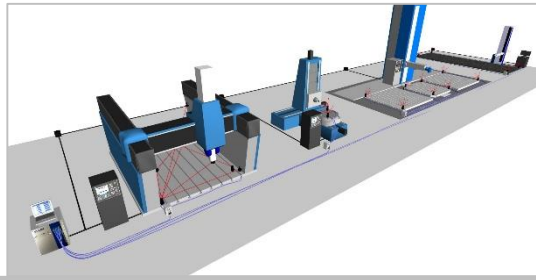



Satellites mounted on 4 corners of working volume
Rack to store rotary table satellites without removing fibers
Additional satellites on kinematic mounts on rotary table

Summary

- Large parts with critical tolerances can be found in many industries
- Measurement on the machine tool offers economical benefit for large parts
- Volumetric compensation, continuous monitoring, application of CMM standards, temperature compensation and software interfaces can be the keys for economic and traceable measurements on machine tools
- Etalon is actively developing solutions in the domain
- Pilot installation at NARMC in progress



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Automation

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Thank you for your attention!