NIKON METROLOGY | VISION BEYOND PRECISION

Nikon 100th anniversary

Comparing CMMs and Laser Radar Method for Correlation Studies

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Motivation of this presentation:

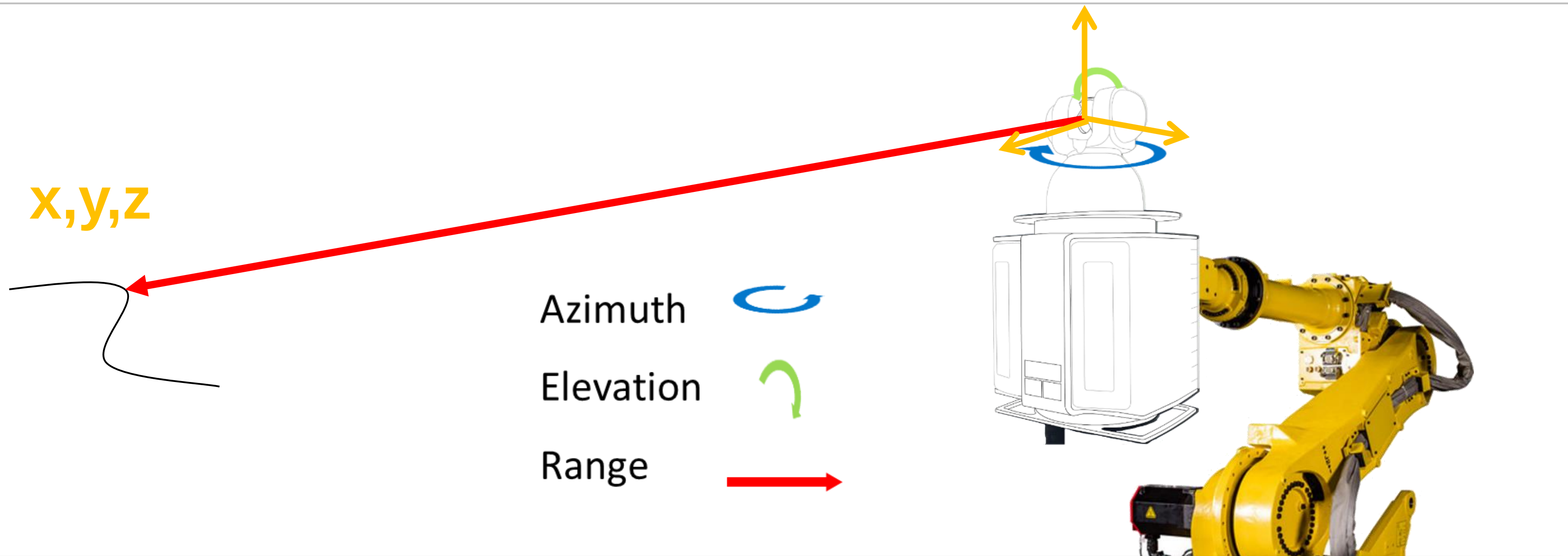
Laser Radar (LR) is becoming important to the automotive OEMs because of its speed and ability to bring automated absolute CMM quality measurements to the production line.

In a recent example, an automotive Body Shop implemented LR in-production and is now getting
CMM quality data on 40 bodies/day with 1000 features/body

Because the transition to new technology is always difficult, today's discussion is how to help users compare touch probe technology (CMMs, Laser Trackers, …) with non-contact technology (LR, white light, line scanners, ...)

The presentation will look at the correlation process by examining portions of a project to replace a Horizontal-Arm-CMM with a Laser Radar

Background: The Laser Radar and its Coordinate System



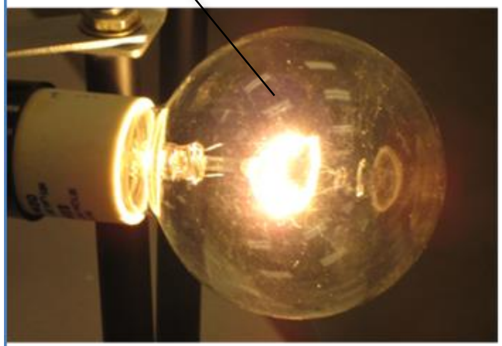
- Like Total Stations and Laser Trackers, the Laser Radar is a **Spherical Measurement System** returning Range, Azimuth and Elevation
- This is converted to cartesian coordinates relative to the Laser Radar
- The LR also returns the **Quality** of each measurement which is important for filtering the data
- Laser Radar is unique in that is measures range using **Heterodyne Interferometry** (sometimes called Frequency Swept Interferometry [FSI])
- The unique range measurement combined with beam **Focusing** allows the LR to operate without targets

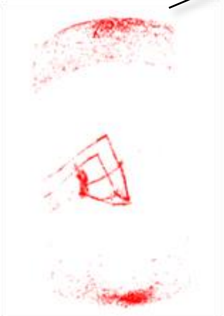
Measurements showing the unique features of the LR

The LR is not sensitive to lighting or temperature and can measure most surfaces

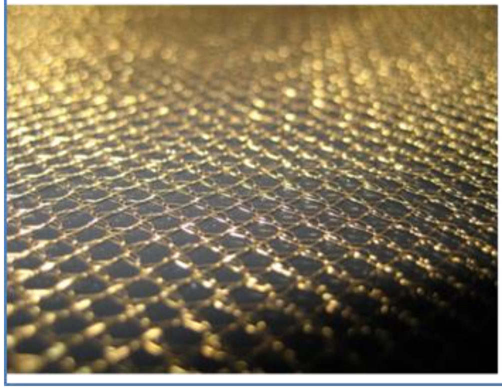
The LR can measure through glass and even measure glass surfaces

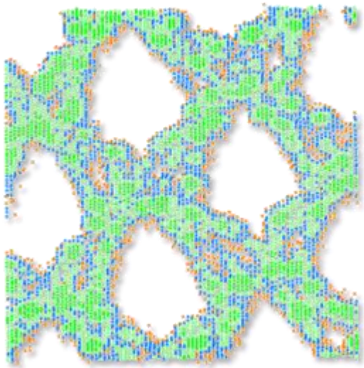
LR Surface Measurements – Standoff greater than 2m





- Filament is approximately 0.5 mm in diameter
- The temperature of a Glowing Filament is between 2000ºK and 3300ºK





- Fine Gold Mesh

Small spot size allows measurement of features

Accuracy, Correlation Errors, and Reproducibility

- For accuracy and traceability of the instruments, ISO 10360 is used:
  - CMM 10360-2:2009
  - LR 10360-10:2016

- When a manual process is changed, a Gauge Repeatability & Reproducibility (Gauge R&R) study would be performed
- With automated systems (LR and CMM) the main source of Reproducibility is the mounting of the part. Although critical, that topic will not be covered in this presentation

- However, to compare instrument's ability to give the **same** answer **Correlation Errors** become more important
- **Correlation Errors** are simply the differences between the reported position of the feature by each system
- In general **Correlation Errors** include: measurement differences, alignment differences, holding differences, and environmental differences

A controlled Correlation Project has a series of tasks

A six step process is presented which strives to

- Minimize differences,
- Work in controlled conditions when possible, and
- At each step build on the confidence generated in the previous steps

These will presented in the order executed.

1. Select the tools to be used including software, a Feature Artifact, and an Accuracy Artifact
2. To compare Measurement Techniques, concurrently measure the Feature Artifact with a high accuracy Bridge CMM and the LR.
3. For confidence building do a concurrent measurement of the Accuracy Artifact using the HA-CMM and the LR.
4. Concurrently measure the Feature Artifact with the HA-CMM and the LR
5. Concurrently measure the User Artifact with the HA-CMM and the LR
6. Analyze the results and report on all the measured Correlation Errors

A controlled Correlation Project has a series of tasks

1. Select the tools to be used including software, a Feature Artifact, and an Accuracy Artifact

1. Tools using in the Correlation Study

Laser Radar

New River Kinematics

Software

MetrologX4

PolyWorks

Bridge CMM

Horizontal Arm CMM

Accuracy Artifact

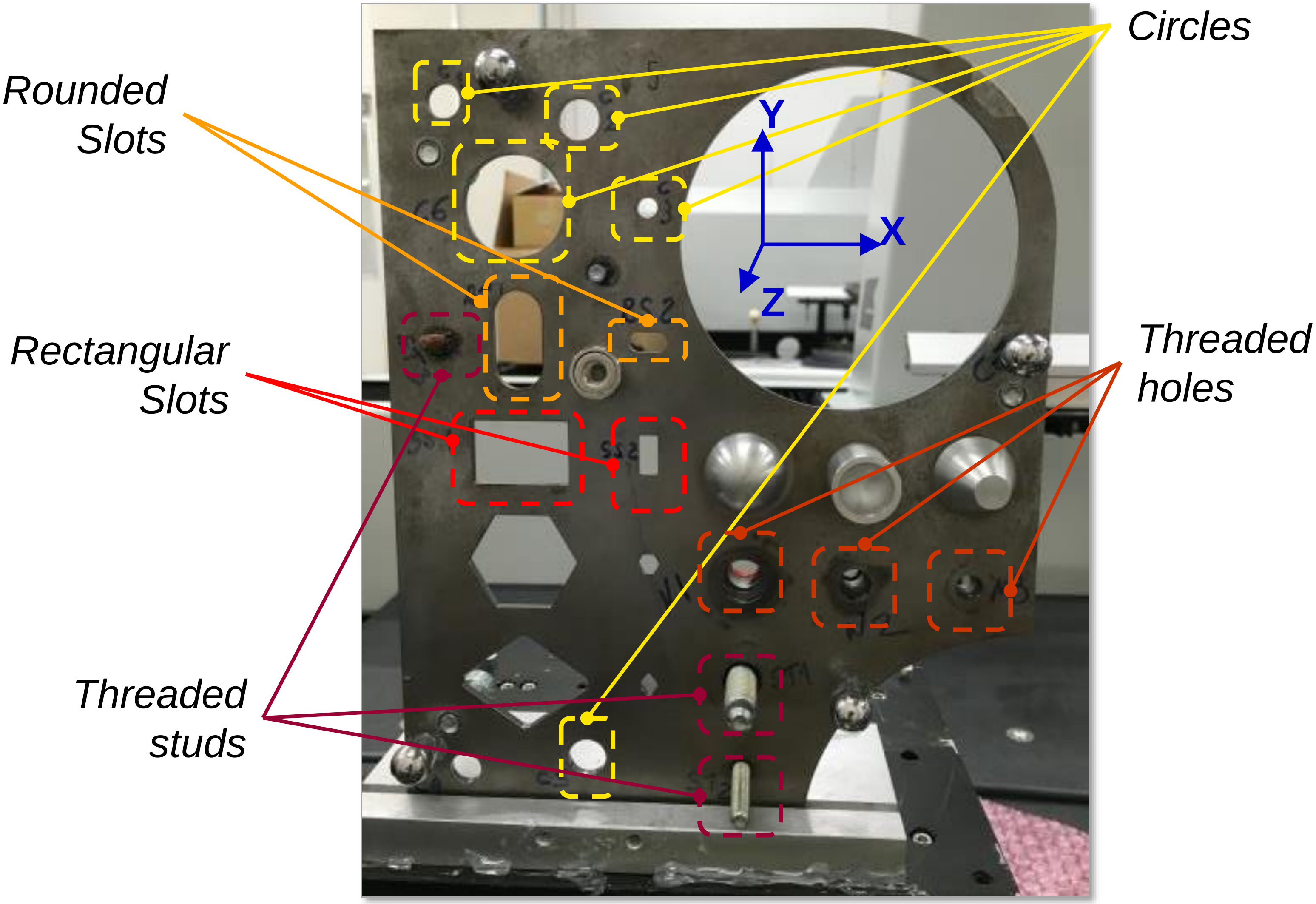
Temperature Compensated Tetrahedron

Feature Artifact

User Artifact with CAD

Normally part of interest

5 Types of Features – 15 features in total



A controlled Correlation Project has a series of tasks

1. Select the tools to be used including software, a Feature Artifact, and an Accuracy Artifact
2. To compare Measurement Techniques, **concurrently measure** the Feature Artifact with a high accuracy Bridge CMM and the LR.

Concurrent measurement should be used to minimize error sources associated with: time, temperature, part holding, etc.

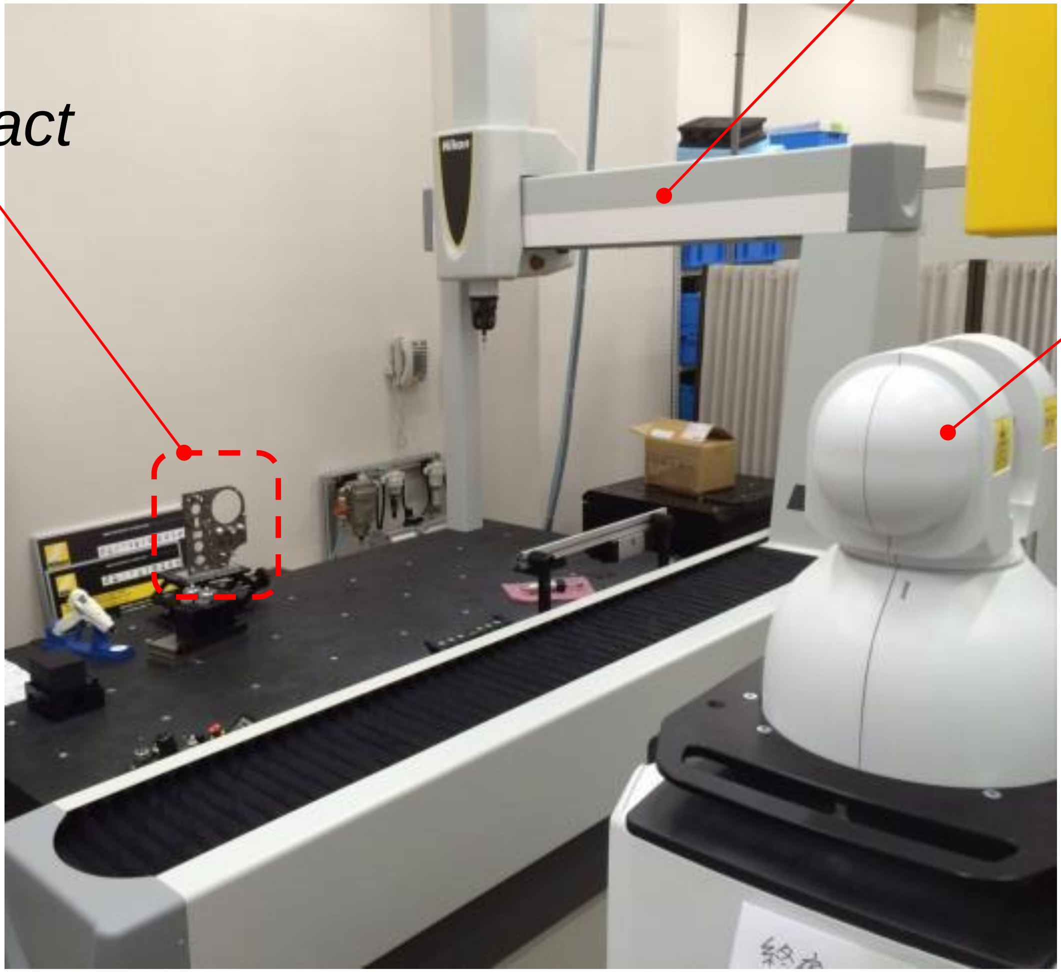
2. Measure the Feature Artifact with High Accuracy

Side by side testing in CMM room (20℃)

Nikon Bridge CMM

Feature Artifact

Laser Radar

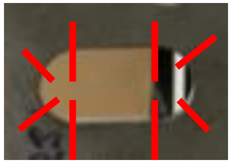


2. When possible use same software for both instruments

Circles

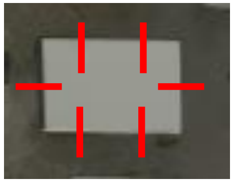
6 lines (6 edges)

Rounded Slots



8 lines (8 edges)

Rectangular Slots

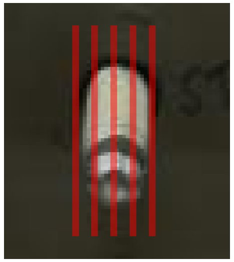


6 lines (6 edges)

Threaded Holes

12 lines
(Point cloud data)

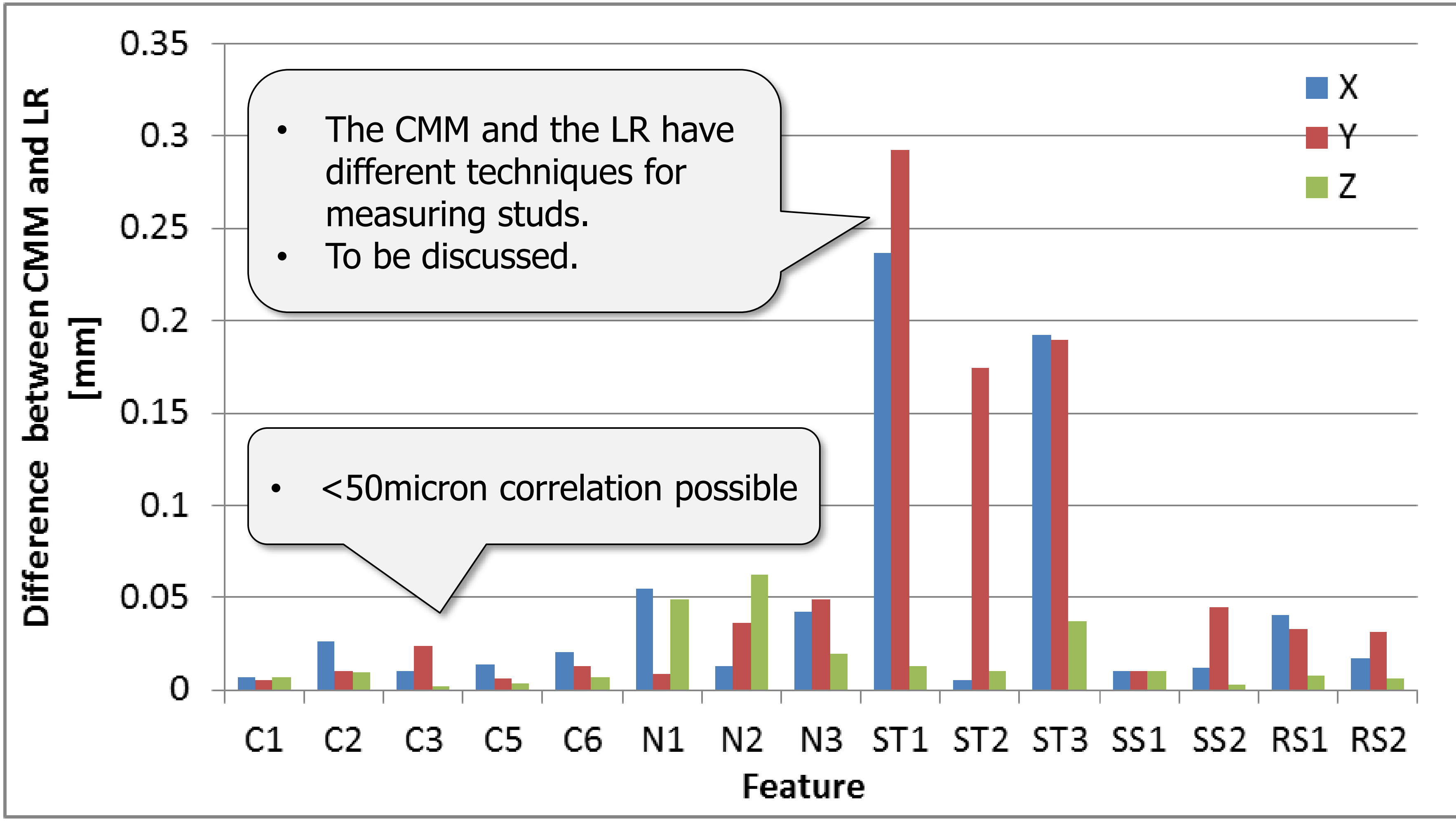
Threaded Studs



xx lines
(point cloud data)

Metrologic was used for this test

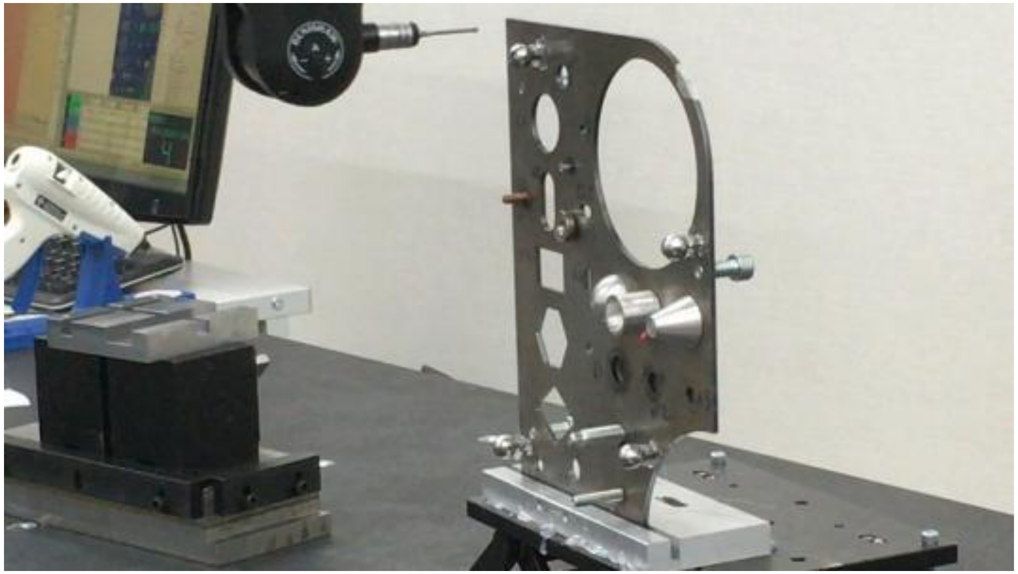
2. Results of Feature Artifact on Bridge CMM + LR



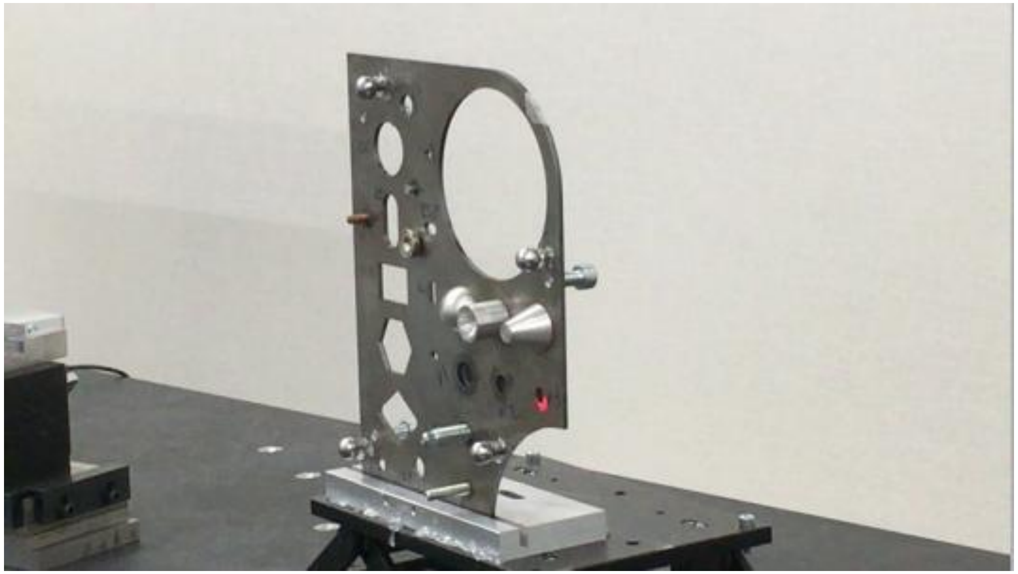
2. At this point productivity can also be compared

CMM measurement with User Methodology

285 seconds / 15 features



7 times faster

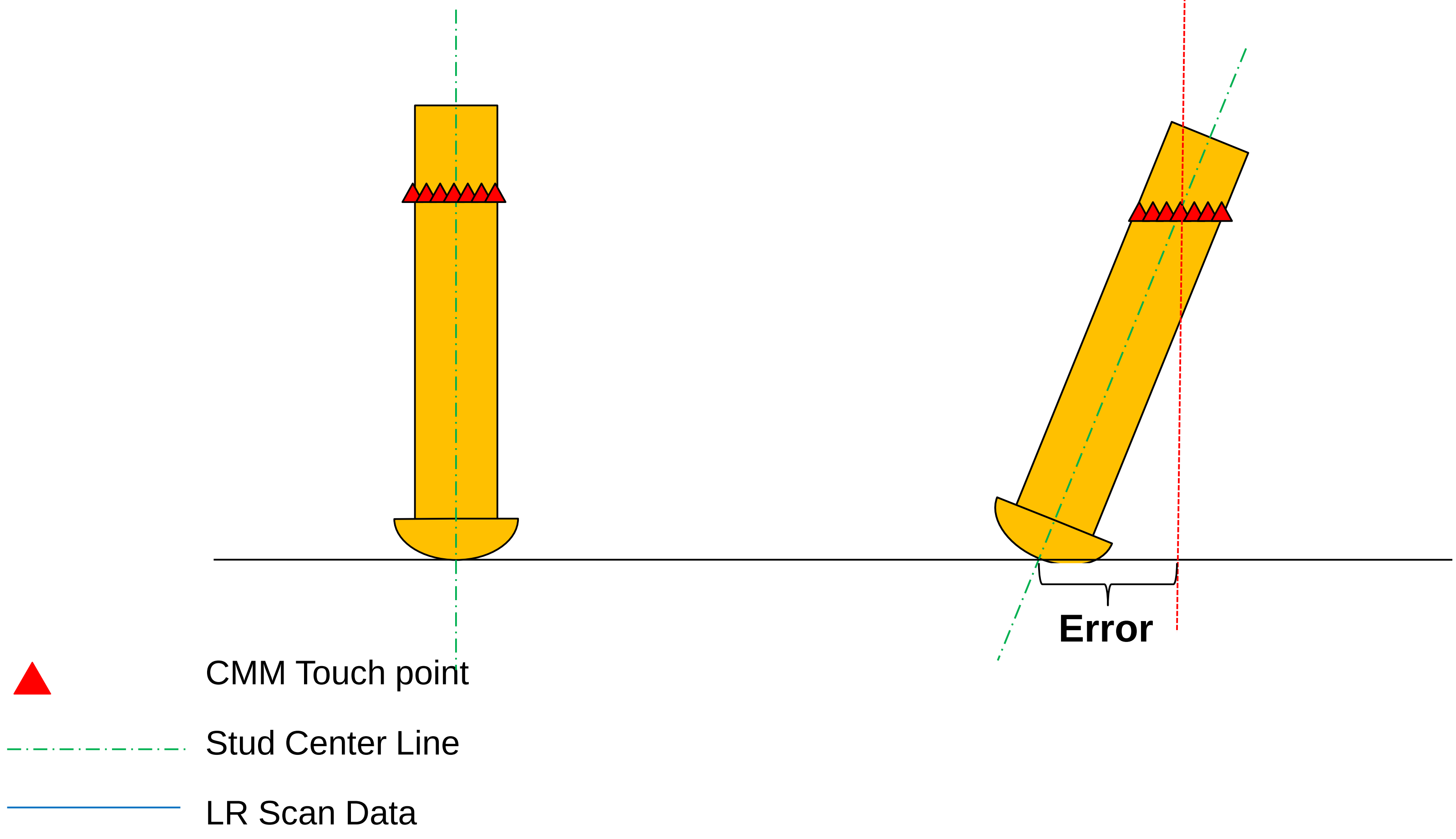


Laser Radar measurement

41 seconds / 15 features

To save time on a CMM, the number of touches is minimized. Some users only measure a few points at the top of the stud and then presume it is normal to the surface

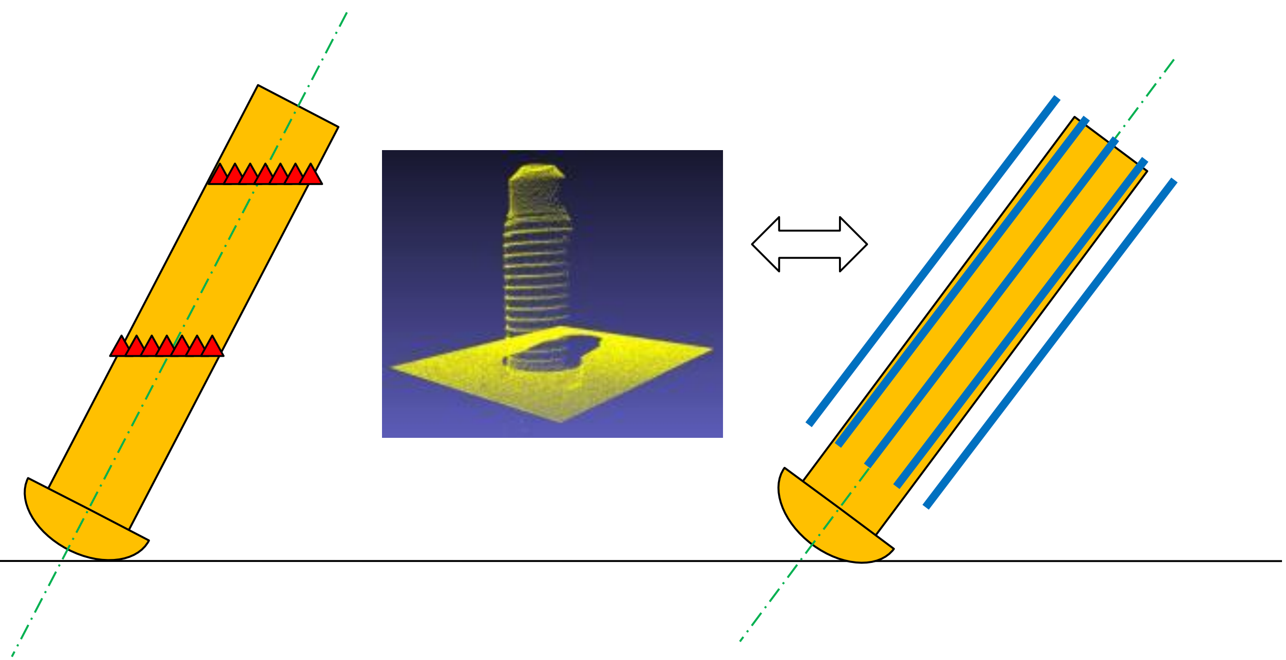
However if the stud is tilted, this measurement technique will create an unexpected error which becomes a correlation error



2. Extra data gives a more consistent result

More touches on the CMM will allow an estimate of the stud axis, but take more time

The LR takes enough data to determine the stud center and axis

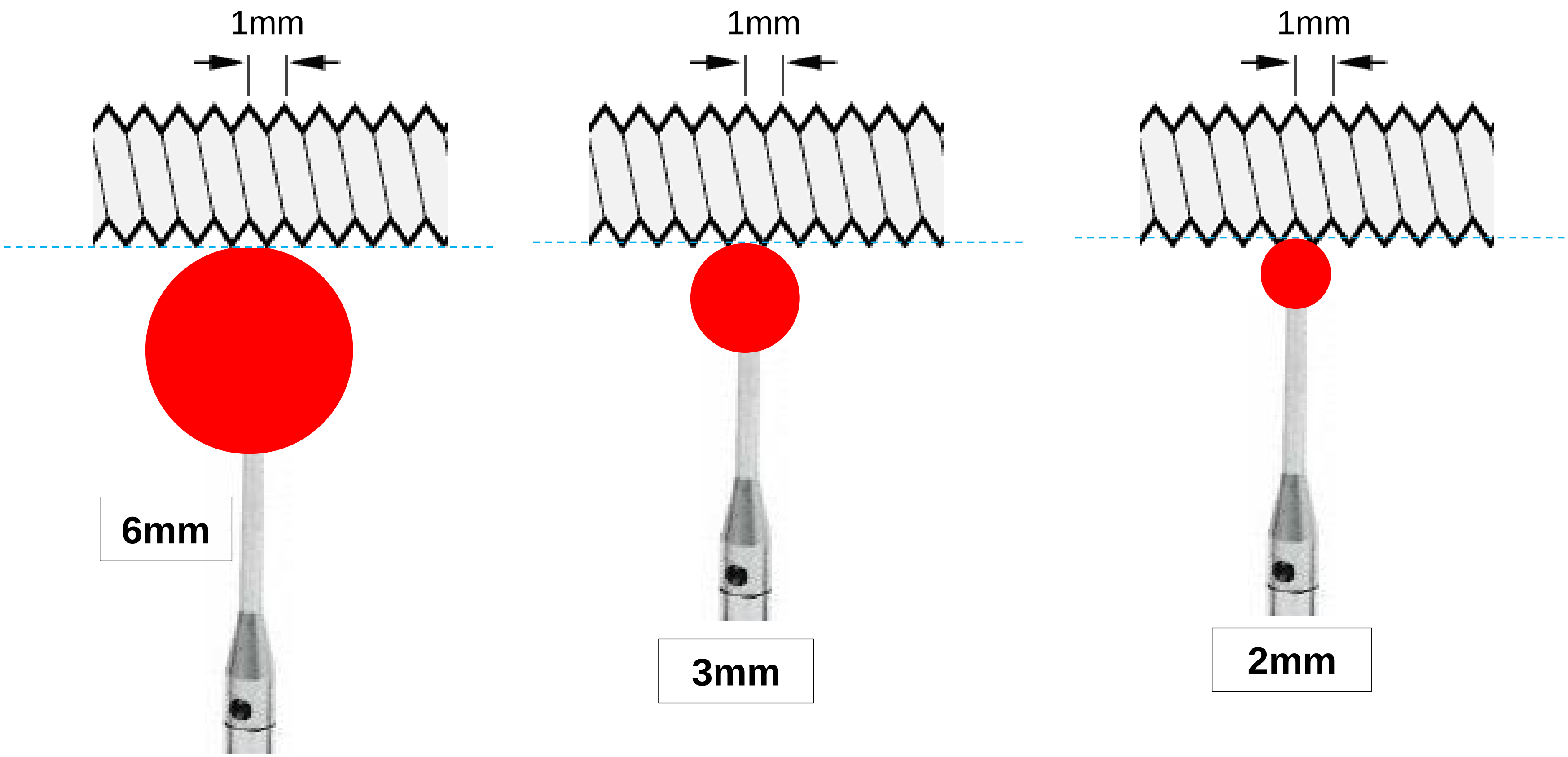


▲ CMM Touch point

Stud Center Line

LR Scan Data

2. Other differences can also contribute to correlation error



Bottom Line

With care and understanding correlations of <100 microns are achieved with a goal of <50 microns

A controlled Correlation Project has a series of tasks

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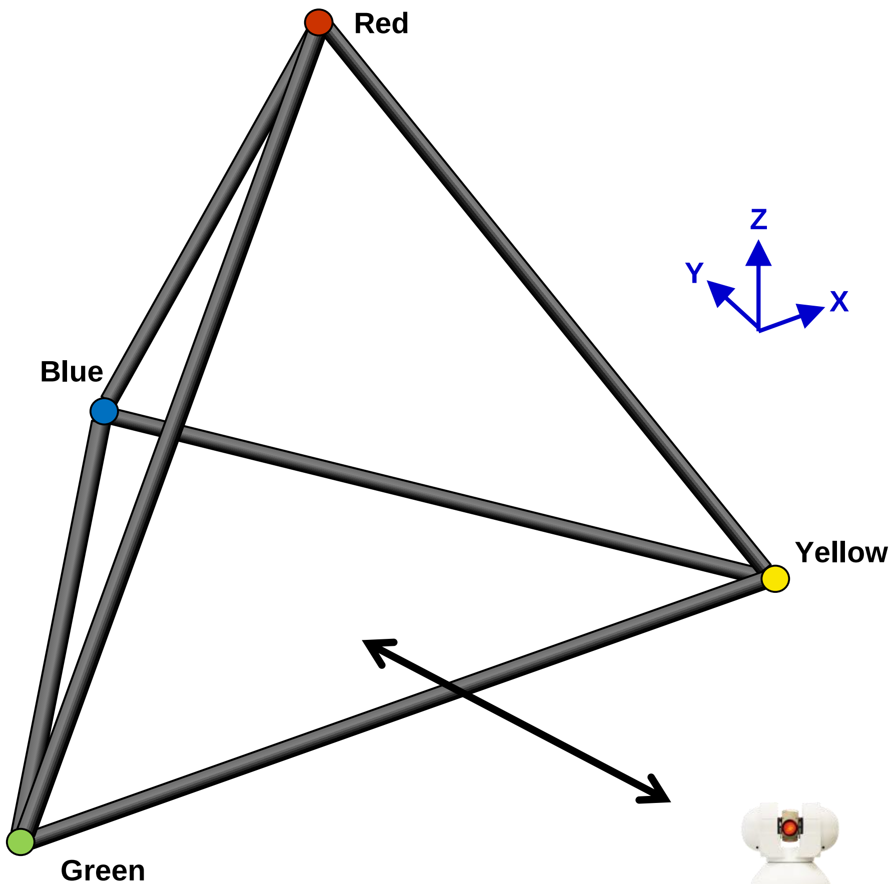
3. For confidence building, do a concurrent measurement of the Accuracy Artifact using the HA-CMM and the LR.

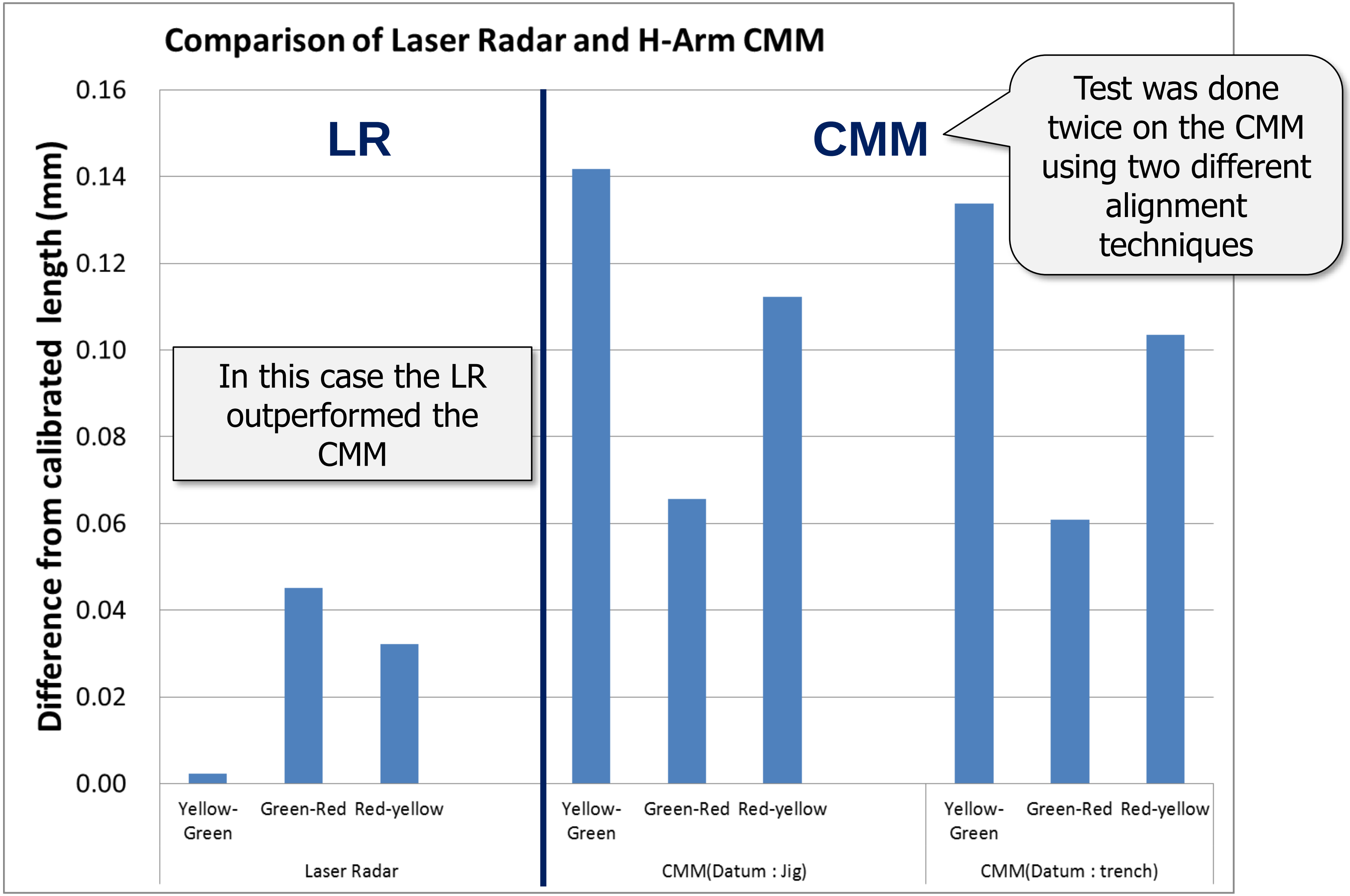
3. Measure the Accuracy Artifact



Yellow-Blue	1498.10580
Yellow-Green	1498.17140
Green-Blue	1499.09920
Red-Blue	1502.29990
Red-Yellow	1502.35750
Red-Green	1502.05420

- 1.5m Tetrahedron manufactured by iNORA
  - SRS-0299-0234
  - Calibrated on 3/3/2016
- Consists of 4 1.5” Balls creating 6 distances
- 7micron uncertainty at k=2 (2σ)
- 0.1ppm/^{o}C TCE
- Suitable for carrying as checked baggage
- The LR was positioned to measure all 4 balls
- Normally a CMM can only measure 3 balls with a single probe orientation

3. Measure the Accuracy Artifact -- Result



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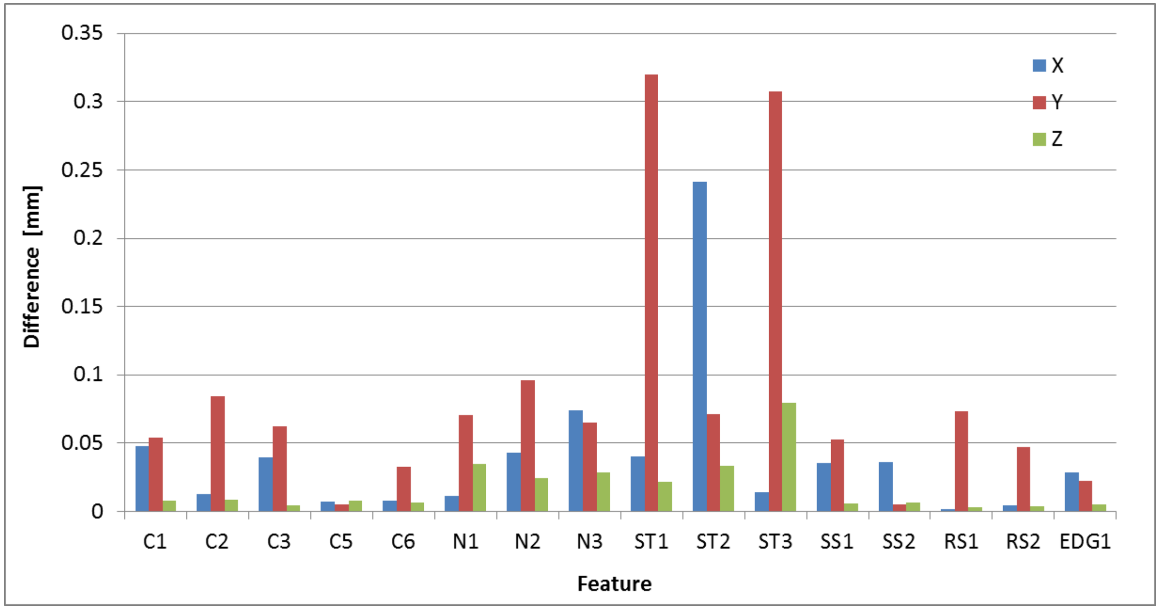
4. Concurrently measure the Feature Artifact with the HA-CMM and the LR

4. Re-measure Feature Artifact with LR and HA-CMM

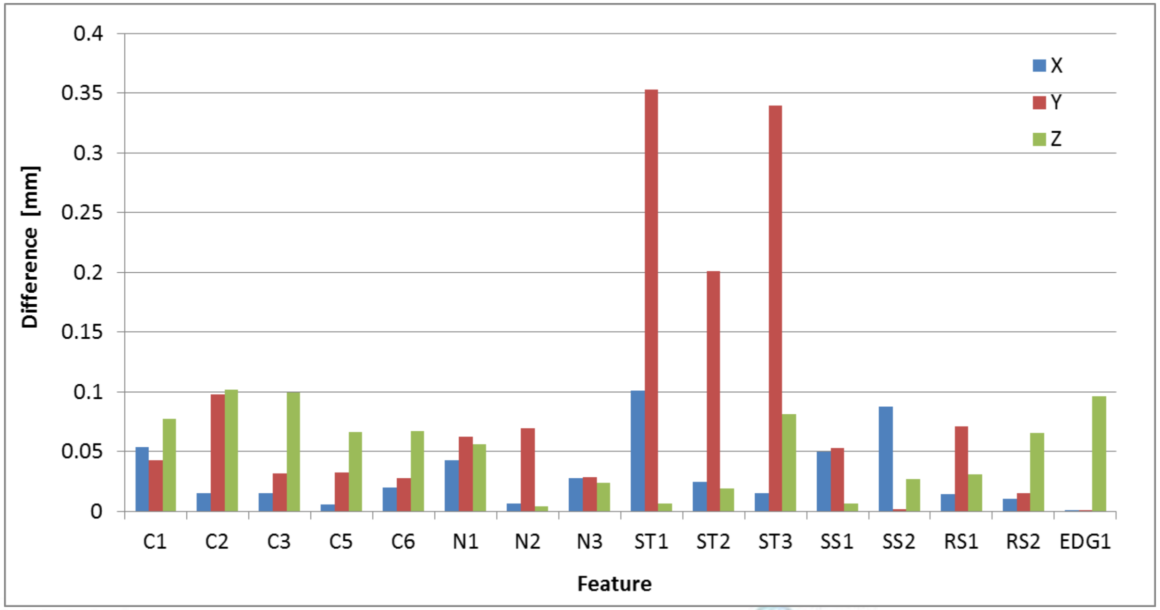
LR vs Bridge CMM

For reference



LR vs HA-CMM

In both cases y-axis is in microns and 50 microns per line



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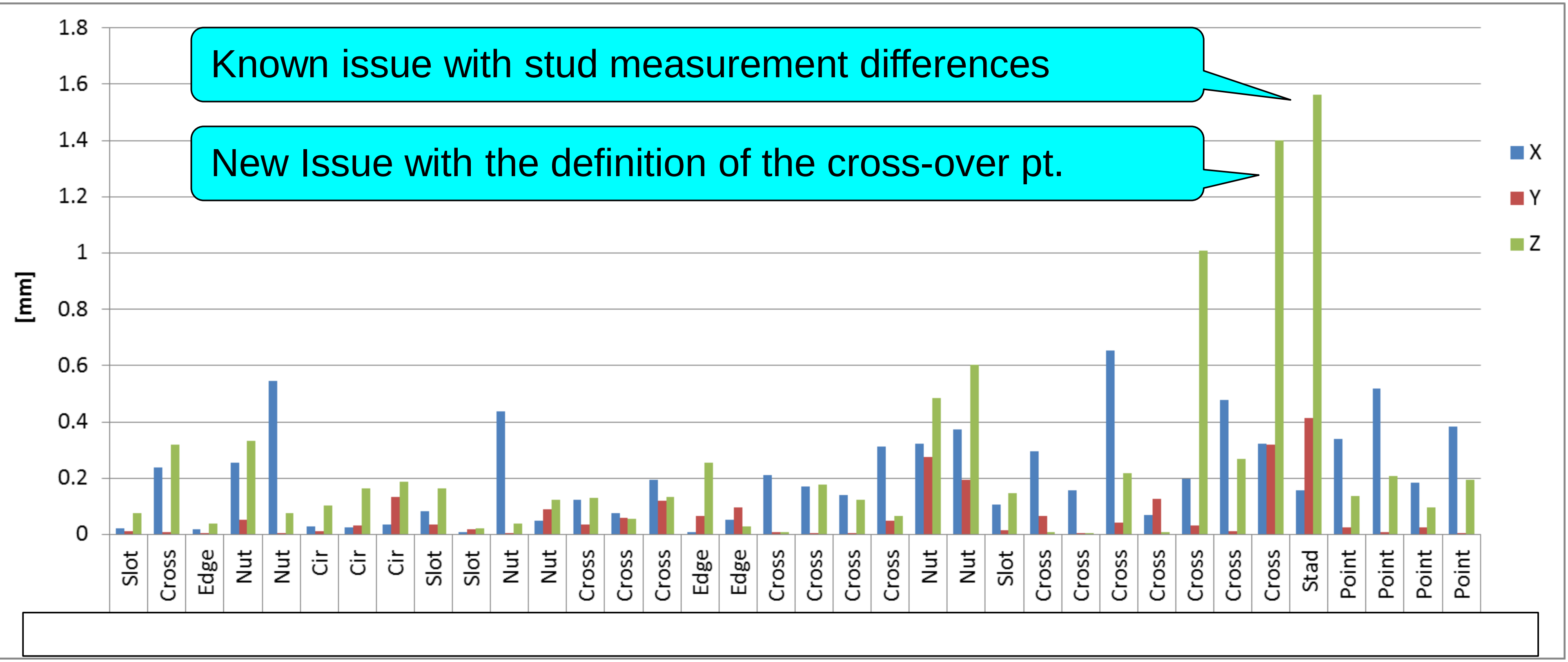
5. Measure the User Artifact – usually a part of interest



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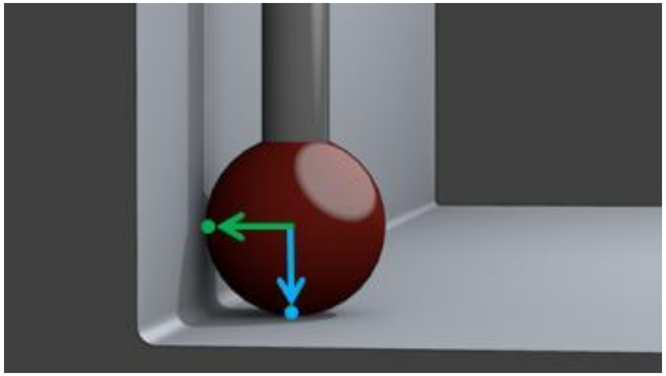
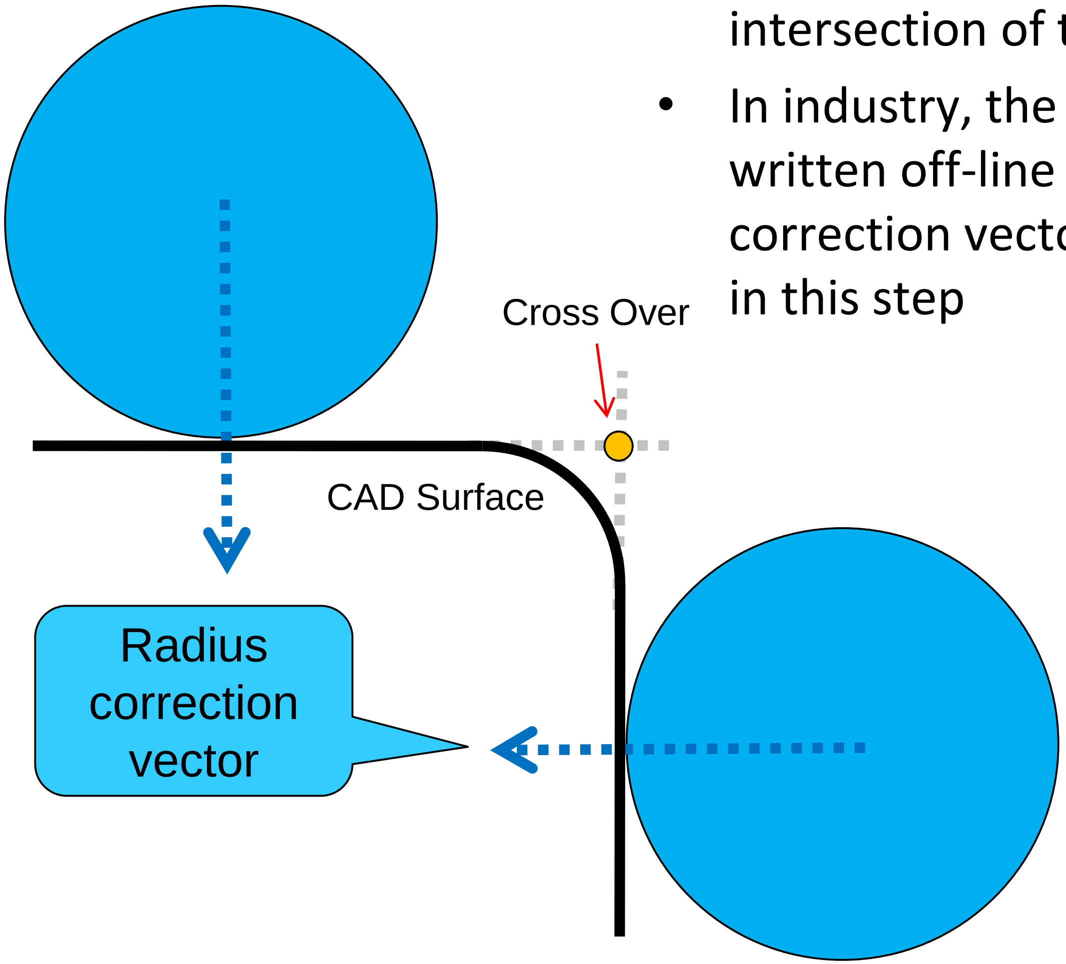
6. Analyze the results and report on all the measured Correlation Errors

6. Reporting – What happened on Cross-Overs?

- Like all touch measurement systems, the measurement is at the center of the measurement ball
- Therefore, there must be a compensation from the center of the ball to the surface
- However, the compensation needs a direction, the radius correction vector, to move the data to the surface along the vector by one radius
- The measurement pictured is a paranoid case however it shows that the error can be as large as the tip radius

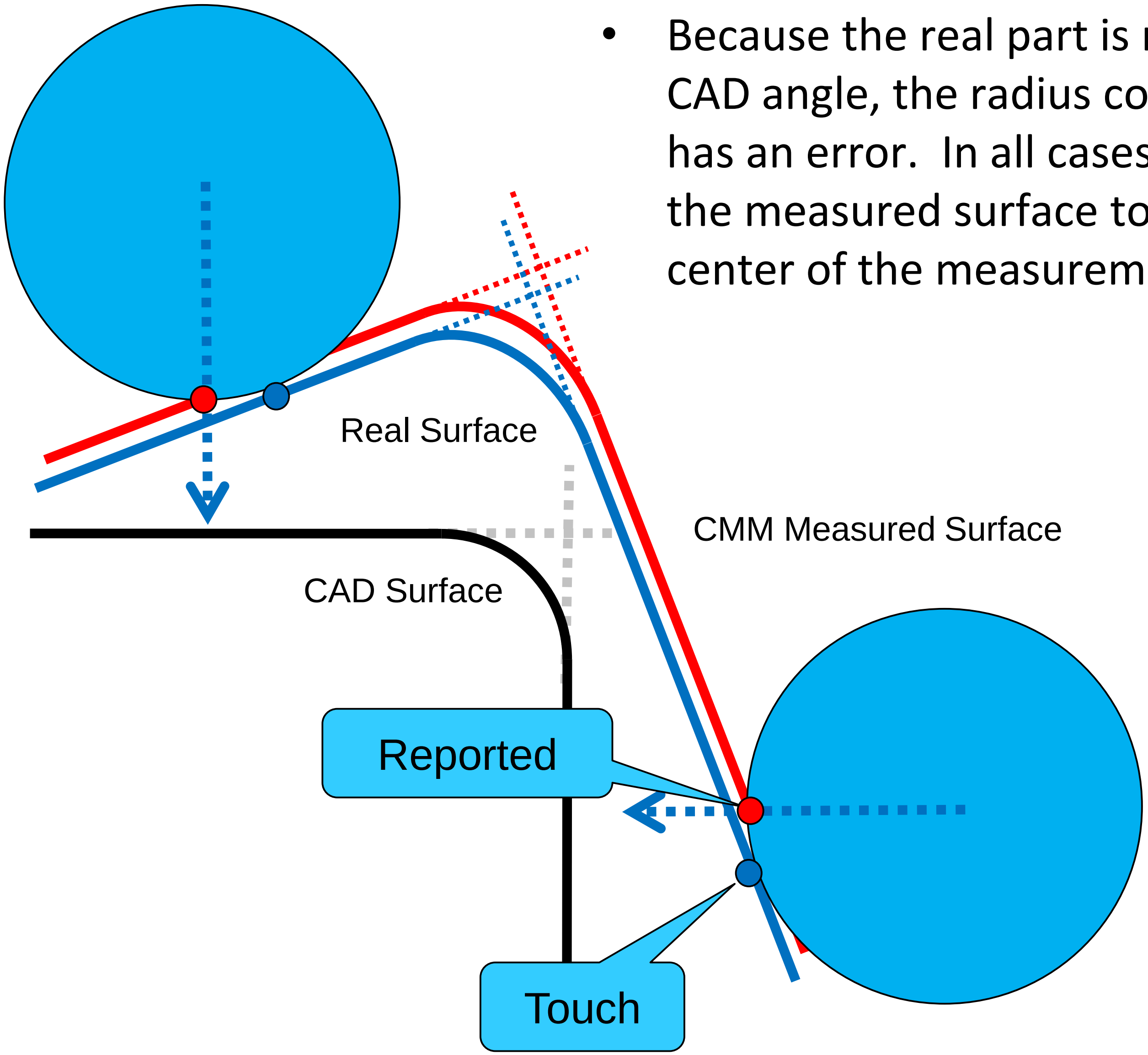


6. Real world – Step 1 – Off Line Programming



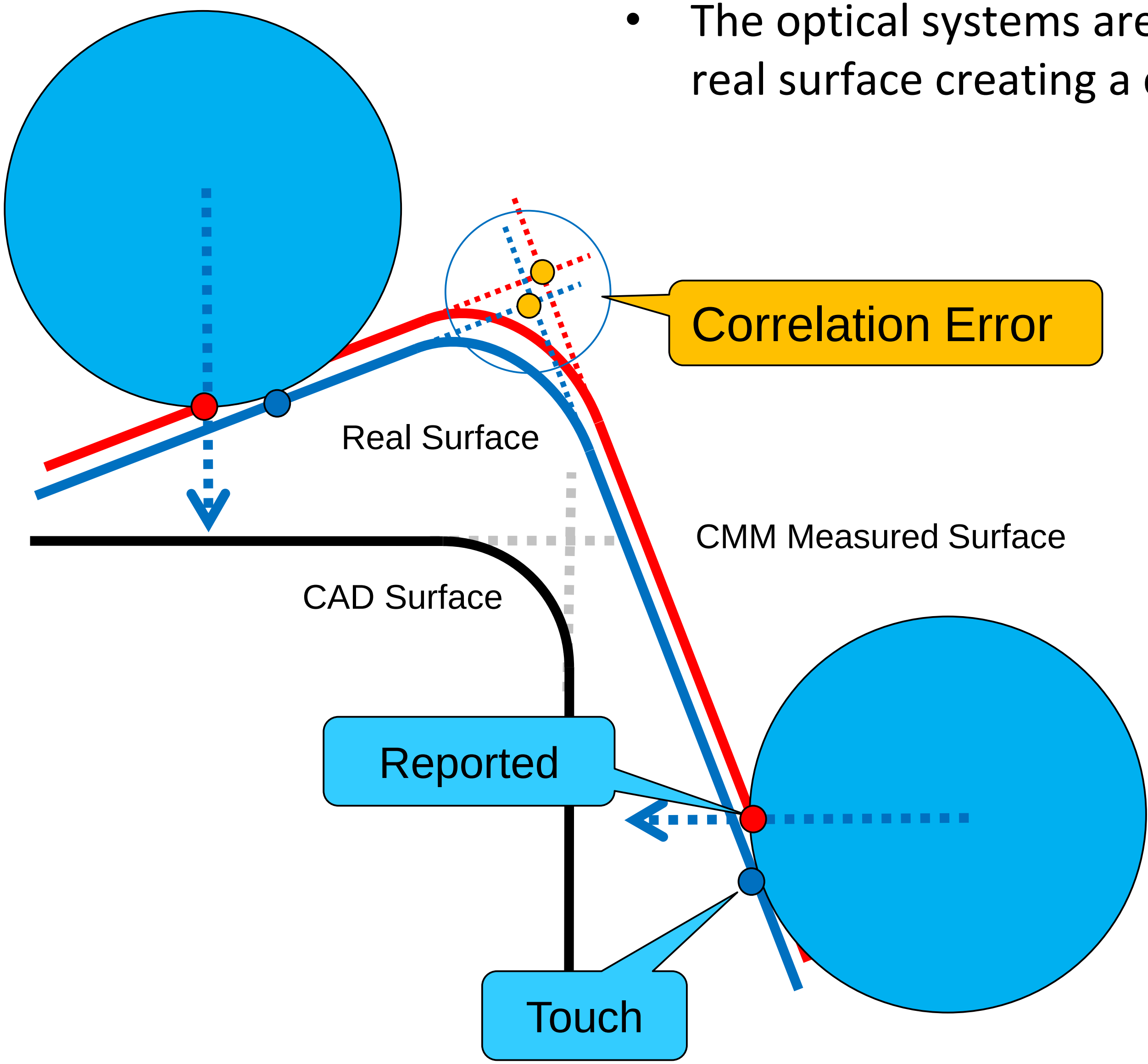
- A cross-over is the intersection of two planes (3 or more touches/surface) or the intersection of two lines (2 touches)
- In industry, the CMM program is normally written off-line using the CAD. The radius correction vector is normally determined in this step

6. Step 2 – The real part



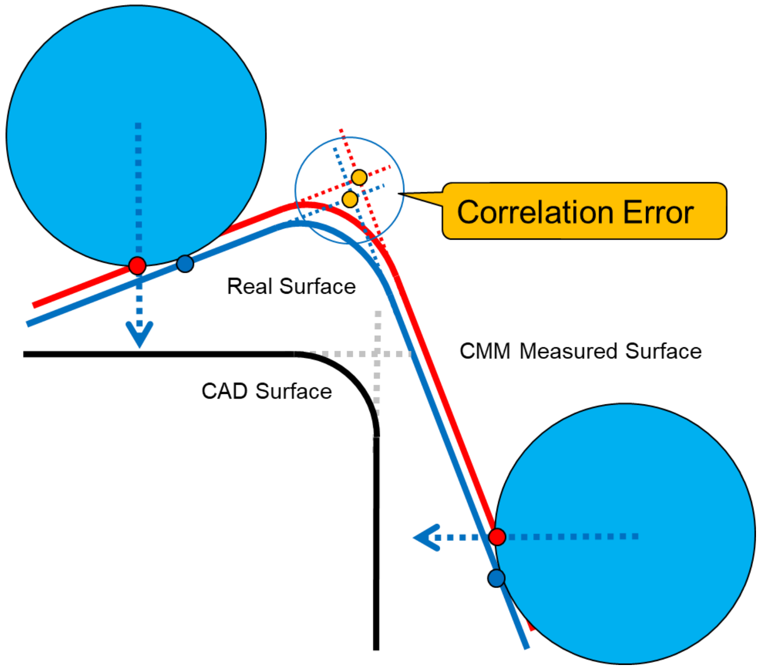
- Because the real part is not at the ideal CAD angle, the radius correction vector has an error. In all cases it will move the measured surface toward the center of the measurement tip

6. Step 3 – Measure Optically



- The optical systems are measuring the real surface creating a correlation error

6. Reporting -- Understand the Correlation Error



- Of course the CMM data can be corrected in post processing. However, extra touches might be required slowing down a process

Typical Error Calculation

Error = Tip_radius*sin(angle)

Tip_Radius = 1.5mm

Angle = 3.8°

Error = 0.1mm

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6. Analyze the results and report on all the measured Correlation Errors

There is always pressure to immediately do step 5 and to not control the error variables. In our experience that is a mistake.

Summary

- The goal was to review some real world issues that impact comparison of instruments
- Experience is that if all 6 steps presented are executed then the final result will be:

  - Excellent correlations with the existing techniques
  - Excellent acceptance of the New Metrology Concepts

Projects are being undertaken with correlations between 100micorns and 50microns.

Thank you!

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