CMM Evolution

The coordinate measuring machine first appeared at the International Machine Tool exhibition in Paris in 1959 exhibited by the British company Ferranti having delivered the world's first commercially available general purpose computer in 1951.

The CMM quickly evolved with a plethora of CMM manufacturers from European Countries, USA and Japan entering the field in the mid 1960's; the uptake of coordinate measuring machines by manufacturing companies rapidly gathered pace after the introduction of the Touch Trigger Probe by Renishaw in the early 1970's.

The touch-trigger probe, invented by Sir David McMurtry, the co-founder of Renishaw, solved a specific inspection requirement for the Olympus engines used on the supersonic Concorde aircraft. This innovative product led to a revolution in three-dimensional co-ordinate measurement, enabling the automatic and accurate measurement of machined components and finished assemblies.

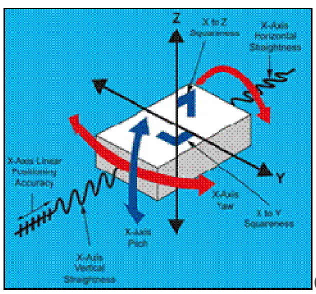
A typical CMM is composed of three orthogonal axes, X, Y and Z operating in a three-dimensional coordinate system. Each axis has a scale system that indicates the position of that axis. The machine will read the input from the touch probe, as directed by the operator or computer program. The machine then utilises the X,Y,Z coordinates of each of these discrete points to determine size and position with micrometre precision.

The touch probe allows for the automatic generation of measured point on the component surface while simultaneously and automatically recording the XYZ position in space of the point taken. This simple patented device has revolutionized the inspection of manufactured parts throughout manufacturing and has played a critical role in the globalization of manufacturing in past decades.

Renishaw dramatically increased the performance capabilities of the CMM even further with the introduction of the motorized probe head in the early 1980's and the coordinate measuring machine as we know it today was born. Further advancements by Renishaw have included the introduction of compact and affordable scanning probes, automatic probe change racks allowing CMM automation and automatic probe stylus changing.

Few, if any, companies can match the innovation levels achieved by Renishaw and their absolute focus on advancement of the industry they serve. Typically they invest 18% of annual sales in engineering and R & D. 2010 turnover was approximately $500 million.

What is remarkable is that during the past 3 decades of Renishaw innovation the core technology behind the Co-ordinate Measuring Machine has remained static. For sure the CMM mechanical structure has been improved by making it lighter with improved repeatability. The development of miniaturized digital CNC controller technology has been effectively applied to the CMM structure providing a more accurate motion path along a defined vector along with the CMM's ability to perform circular motion paths rather than just straight line moves together with the ability to operate the CMM structure at higher speeds and acceleration levels. All of these improvements to the CMM have been incremental and more based upon technological advancements from outside the industry than internally generated innovation.



One innovation that has occurred has been the construction of the CMM structure from new high technology alloys materials, moving away from the original granite and steel designs. These alloys provide a lighter, stiffer structure while at the same time improving reaction to, and dispersion of, temperature changes and actually result in less deformation of the CMM structure than that experienced by the slowly reacting granite structures. Integrated with the alloy structures are measuring scales, typically from Renishaw, that are located in sub-straits mounted to the CMM structure. The measuring scales are free and in-dependant of any CMM structural movements increasing dramatically CMM accuracy even in non-perfect environments. Granite structures are also less predictable due to the inconsistent material properties of the natural product and have their scales rigidly mounted. In addition, with the introduction of low-cost PC computation, geometric error compensation has been harnessed allowing the accuracy of a CMM to be improved considerably beyond what is achievable by using a mechanical accuracy only structure and at the same time reducing CMM purchase costs. Today the operation of advanced jet airliners is totally reliant upon 'fly by wire' computer based technology; so then are modern Co-ordinate Measuring Machines whereby the actual position of the recorded probe data points, from the measuring sensor, are derived from the real-time software running in the background and calculating the actual probe position rather than just providing its assumed position.

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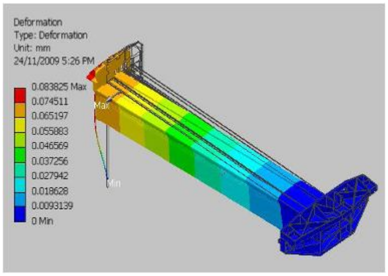


Traditional" CMM companies, many with CMM designs dating back 20 years or more, are still manufacturing using the original materials adopted by the CMM industry before computerised finite element analysis modelling arrived allowed dynamic structural behaviours to be understood and designs to be improved based upon the modelled data. Many of these companies sell tradition; in reality they are supplying outdated and archaic design concepts and obsolete for today's modern manufacturing environment. Much of their resistance to change comes from their investment in internal house granite production facilities which the newer CMM designs render obsolete.

Small start-up companies based in the emerging markets of China and India also produce granite structures; granite blocks are in cheap and plentiful supply and require only a minimum effort to produce a CMM frame design and have a fast time to market minimizing investments. (In fact more investment is made in cover design and tooling for product aesthetics than in the rest of the CMM structure combined). This scenario was also followed by CMM builders of the 1980's and 90's in both Europe and USA resulting in a large CMM supplier base. The majority of these suppliers have now been consumed by economics pressures leaving a huge installed base of obsolete machines behind. It's inevitable that a consolidation of the 'new world' CMM builders in China and India will also occur in the coming future.

Another Measuring Innovation from Renishaw

After more that 10 years in development and the investment of many tens of millions of dollars in Research & Development expenditure Renishaw has introduced the largest single step-change ever seen in the CMM industry. Renishaw has introduced **5 Axis Measuring Technology** to market whereby the CMM structure role in the measurement process is dramatically reduced and 'dumbed down' resulting in huge improvements in CMM measurement productivity and with improved metrology.

5 Axis is disruptive technology to the traditional CMM supply base even though the benefits to the end-user are overwhelming. OEM resistance to Renishaw 5 axis is due in main to the fact that to access this new technology requires utilisation of a Renishaw CMM controller. Most OEM's see the CMM motion controller as part of their domain (even though most purchase in and 'badge' their motion controller) and as a consequence have taken a stance not to offer this new revolutionary technology to its customers. The complexity of driving a continuous motion head with third-order polynomial interpolation algorithms with fully integrated touch probe and scanning capabilities left Renishaw no option but to seamlessly integrate all probing functions with the much simpler 3 axis CMM motion in order to deliver a seamless, risk free, next generation solution to market. In addition new international standards on CMM interoperability between brands driven by end user demands insists that all CMM probe calibration and data mapping is completed and stored at a CMM controller level allowing the application software packages to be 'plug and play' and the CMM metrology integrity to be independent of these application software packages.

A CMM Measuring Philosophy Change for Customers

Introduced integral with 5 Axis technology are new CMM feature based measuring routines including 'Head Touches' whereby the complete geometry of a part feature is inspected within the 5 Axis Head completely eliminating the CMM structure from having in role in the measuring function. Not only do 'Head Touches' triple CMM productivity they also dramatically improved the accuracy of measured data by eliminating the CMM structure errors from the measuring activity. Other unique measuring routines introduced with 5 Axis CMM Scanning allow the collection of thousands of data-points per second and only require a single linear axis motion of the CMM.

COORD3 is embracing the benefits offered by 5 Axis Technology and is one of only a few CMM supplier 100% focused on delivering 5 axis products to customers utilising the full complement of Renishaw Technology Components.

CMM History

The Coordinate Measuring Machine first appeared in the early 60′s having been first shown by the British Ferranti Company at the Paris machine tool expo in 1959 and the Coordinate-Measuring-Machine industry was immediately born. The earliest Co-ordinate Measuring Machine was a 3D device with a simple DRO displaying the XYZ position
of the X Y Z Machine.

There has been much dispute over the years concerning the original inventor of the Co-ordinate Measuring Machine, which has been abbreviated to CMM or CMM's over the years; the nomenclature CMM Machine has now become the industry standard term for 3D Measuring Machines. The first CMM devices were a Portal Frame CMM with Hard Probe, shortly after the introduction of the Ferranti Metrology Cantilever CMM with D R O and fixed CMM probes the Italian company DEA (Digital Electronic Automation Spa) introduced their C.M.M. just a few months after Ferranti. Ferranti (now International Metrology Systems or IMS) probably introduced the first DCC CMM (Direct Computer Assist) but DEA claim to have introduced the first CNC CMM. LK Tool, also from the UK has long claimed to produce the first Bridge CMM that has become the standard configuration for CMM Machines in past years. Cantilever CMM, Bridge CMM, Gantry CMM, Horizontal Arm CMM, Portal CMM, Moving Table CMM, Fixed Bridge CMM and Articulated Arm CMM have all become other common configurations for CMMs.

The C.M.M. industry today produces over 6000 CMMs annually; C.M.M can come either as a Manual CMM where the CMM Operator manually guides the Manual CMM around the part to undertake CMM Inspection or as a CNC CMM where the CMM is driven automatically from the CMM Part Program.

Each industrialized country of the world has created a domestic CMM Industry. The largest proliferation of CMM Companies has come from the UK. Ferranti Metrology started the UK CMM Industry and licensed their technology to Bendix Corporation in the U.S after a short period where Bendix acted as CMM Sales Agents in the US for the Ferranti CMM. Bendix CMM became the dominant CMM Supplier with its Cordax CMM during the 60′s and 70′ later becoming known as the Sheffield CMM or Sheffield Company or Sheffield Metrology . The Cordax CMM was primarily a Cantilever Style Manual CMM with Hard Probes migrating to Touch Probes from Renishaw as the technology became available. DCC CMMs from Cordax and Sheffield also became popular as computers entered the field of CMM Metrology.

IMS machines include the Impact CMM, Merlin CMM, and the Umpire CMM a flexible shop-floor gage. LK CMMs are the G80 CMM, G90 CMM, G80C CMM, G90C CMM and use LK DMIS or Cameo CMM software.

Other UK CMM Manufacturers have included W & A Metrology, Status Metrology, Eley & Warren, LK Tool, Notsa, Vickers Maxicheck, Kemco, and International Metrology Systems or IMS. As part of the local industry consolidation Notsa was acquired by Vickers Maxicheck, which was subsequently taken over by Ferranti Metrology. LK CMM known for a while as LK Tool and subsequently L.K. Metrology was a spin off from Notsa while Kemco and Eley Metrology were started by ex LK employees. LK was acquired by the Belgium Metris Metrology Company and now past acquisition of Metros by Nikon now forms part of Nikon Metrology of Japan although the CMM’s are still marketing under the Metris Metrology Brand.

Italian CMM Companies have included D.E.A., Poli, Coord3, Fratelli Rotundi and Prima. Prima Industries were focused on Shop-floor CMMs and the CMM Gage and were the first to recognize Flexible Metrology as the future of Shopfloor Gaging, they were acquired by DEA in the early 90′s who also purchased the Renault CMM Company from France. DEA are one of the most famous CMM Brands and DEA CMM’s can be found in most countries of the world; its brands of CMM include the DEA Omicron, CMM, DEA IOTA CMM, DEA Epsilon CMM, DEA Beta CMM, DEA Delta CMM, DEA Gamma CMM, DEA Swift CMM, DEA Omega CMM, DEA Bravo CMM and DEA Lambda CMM. DEA are famous for having produced the largest Gantry Coordinate Measuring Machines ever built. DEA were also the inventor of the slant bridge CMM that now forms the Hexagon Global CMM range design. Many of the upcoming

Chinese CMM builders have also copied the patented DEA slant bridge CMM design.

French Coordinate Measuring Machine companies have included Renault CMM whose CMMs were marketed in the US by Federal CMM alongside their own CMM’s that originated with the USA company Boice, CMA who changed their name from MFO after a merger with Tri-ax and Tri-Measure specialized in Ceramic Structure CMM’s. CMA was eventually acquired by Metrologic of France who ceased CMM production to focus CMA on the CMM retrofit market. French CMM Software included Prelude Inspect; now part of Matra and Metrologic the developers of Metrolog II metrology software and one of the few independent CMM software development companies..

German Coordinate-Measuring-Machine companies include the industry leading Zeiss CMM who is the largest along with Wenzel, Mora, and Steifflmeyer, the latter three are all famous for Horizontal CMM's. Wenzel remains a family owned CMM company and one of the largest Renishaw Probe customers. Carl Zeiss CMM produces the High Accuracy CMM with Scanning Probes while most other CMM brands use the Renishaw Touch Probe. Zeiss CMM names include Zeiss Prismo Vast CMM, Zeiss WMM CMM, Zeiss UMC CMM, Zeiss UC CMM, Zeiss UPMC CMM, Zeiss Eclipse CMM, Contura CMM, Vista CMM, Zeiss DuraMax, Zeiss Scan Max. The Zeiss Horizontal Arm CMM are named Zeiss Carmet CMM, Zeiss SMC CMM and Zeiss SMM CMM. Zeiss Probes are the XXT, Vast Probe, HSS Probe Head, RDS/RST, Zeiss also manufacture the manual CMM called ScanMax which uses ScanWare Software. Zeiss offer the Calypso CMM Software as well as Holos CMM Software, and have developed CMM-OS to allow 3rd party Metrology Software to be interfaced to Zeiss CMMs. One other German CMM manufacturer is Leitz, which has always specialized in the Ultra High Accuracy CMM and was acquired by Brown and Sharpe in the early 90′s. The Zeiss Vast CMM system has dominated the automotive power train application over past years although starting to become challenged by the Renishaw REVO 5 axis scanning probing system. Mora went into bankruptcy in 2009 and were taken out of bankruptcy proceedings by the upcoming Chinese CMM Company AEH who are attempting to use the MORA brand to penetrate the European market with its Chinese build CMM Machines.

Switzerland produced the SIP Company manufacturer of the SIP CMM another High Accuracy CMM. In addition Switzerland is the home of Metromec the first mainstream supplier of PC based Metrology Software, which became popular with most CMM Manufacturers in the mid 80′s and CMM Users who started looking for User Friendly CMM Systems before going bankrupt. Today Metromec is a wholly owned subsidiary of Wenzel and its in-house CMM software supplier with its CM Software and Quartis CMM software.

Sweden had only one Coordinate Measuring Machine Supplier C.E. Johansson Company known as CEJ or C.E.J. this company was merged with Ram Optical the Metrology Division of Newport in 2000 and was subsequently sold the Hexagon and became an integral part of the Hexagon Metrology Group.

Spain has entered the CMM industry in recent years with the Trimek CMM although the company has failed to become an international participant in the global CMM industry.

The United States has its own CMM Manufacturing Companies all producing CMM's. Sheffield was the dominant name in the CMM Market with its Apollo RS CMM, Cordax CMM, Sheffield 1808 in Manual CMM and DCC CMM configurations. The later Sheffield CMMs were the Discovery CMM and the Endeavour CMM. Sheffield became part of Giddings & Lewis in the late '80′s and later became known as Sheffield Measurement. It was acquired by Hexagon Metrology and now is an integral brand in the Hexagon Metrology Group. Its CMM-Software called Direct Inspect and Measure Max, were one of the most well known and its CMM Programming Language was Sheffield FLB. CAD Path Software provided the CMM Programming capabilities using CAD data. Federal Products built CMM's for a few years and in addition marketed the Renault CMM. Today Brown & Sharpe (BNS) are the largest Coordinate Measuring Machine builder; Brown and Sharpe acquired Leitz, and DEA in the 90's in an effort to consolidate the CMM Industry. Brown and Sharp produced CMM-Products including the Xcel CMM, Microval CMM, Reflex CMM, Mistral CMM, Scirocco CMM, Global CMM, Gage 2000 CMM in addition to other Metrology Tools. BrownandSharpe CMM Software included MM4, Avail, Tutor for Windows and PC DMIS. Wilcox and Associates are the developers of PCDMIS and were acquired by Hexagon who is also the new owners of BrownandSharp as the exclusive supplier of PC-DMIS. Other domestic CMM Builders included Helmel, Taurus, Elm Systems, Resource Engineering, Starrett and a few small others. Starret stopped development of its own CMM Software and marketed the Metrolog product under the name Apogee and the QC5000 CMM Software from Metronics until finally deciding to terminate its CMM business. Hexagon Metrology acquired the assets of the Starrett CMM group merging it with its Sheffield Metrology business providing ongoing customer support for Starrett customers.

With the acquisition of Brown & Sharpe by Hexagon a new company was formed called Xygent who was the owner of Xact Measure a next generation CMM Software with full CAD capability with a special metrology focus on GD&T. This product represented a challenger to PC DMIS. XactMeasure was taken off the market following the
acquisition of Xygent by Hexagon Metrology.

Japan has several Coordinate Measuring Machines builders including the world's largest Metrology Equipment manufacturer Mitutoyo also known as MTI who export their products to a global market. The Mitutoyo Bright CMM, Bright Apex CMM are probably the best selling CMM globally. Tokyo Semitsu licensed their original CMM Technology from Ferranti, and Tokyo Boeki is a producer of Arm CMM's. Mitutoyo over the years used nomenclature for their CMM's like FN Series. BHN Series, BN Series with the BHN504, BHN706 and BHN715 being among the most popular. Mitutoyo CMMs and Mitutoyo CMM were built mechanically accurate until the launch of the Bright CMM. Mitutoyo fell foul of export regulations associated with Coordinate Measuring Machines and suffered under a 5 year export ban on its products which was removed in early 2011. Mitutoyo has an extensive range of Gantry, Horizontal ARM CMM and high Accuracy Legex and Nano CMM's in Japan which do not
receive active marketing in western CMM markets.

Korea has one CMM Manufacturer called Dukin CMM Company which also has manufacturing plants in China. Their machines have not been highly successful in export markets todate. IMS has also trasferred most of its remaining CMM manufacturing operations to Korea.

China became the largest CMM market in the world in 2010. Hexagon and Zeiss are very strong in China and both manufacture locally. In addition to selling in China under the Brown and Sharpe, Sheffield and DEA brands Hexagon also has purchased a local CMM builder Serein. There are currently over 30 CMM manufacturing companies in China including AEH, Leader, Xian Lead and Qingdao Friend. Almost all Chinese CMM companies are manufacturing slant bridge design CMM bridge machines; and all are manufacturing from granite. Few Chinese CMM builders produce more than 100 units per annum and all are using either the Renishaw UCC Controller or the Pantec Eagle CMM Controller that is also used by Wenzel. Pantec is based in Lichtenstein and is challenging Renishaw as the supplier of CMM Controllers to the CMM builders that do not have CMM Controller technology in-house. In addition only AEH has its own CMM software. Rational DMIS, Arco CAD and CMM Manager are all popular CMM software's being used by China CMM builders. Wenzel and Coord3 are also building CMM machines locally in China. It is very probable that the same CMM consolidation of the western CMM manufacturing base will occur in China in coming years. Price is the only sales tool of the domestic China CMM builder and with China costs increasing dramatically these local companies will lose their competitive edge in coming years. The only way any will survive is by partnering with western technology and only Coord3 and Wenzel remain available as independents.

India CMM Machines. India is also an emerging market for CMM units with several small companies emerging. By far the largest is Accurate Gauging who transferred the original Poli CMM manufacturing operation to India and produce their granite needs internally. Accurate CMM originally had a partnership with Wenzel CMM company; this relationship has expired and the Accurate bridge CMM range bears a very similar characteristics to the Wenzel LH range of Bridge CMMs. India is expected to maintain its low manufacturing cost structure much longer than China and could play a significant role in the coming decade. China granite is used by all of the major CMM builders due to its cost but China granite appears to be running out due to the long time rumour of the China government banning the continued decimation of the granite mountains. China has started sourcing its granite in India due to these reasons and the plentiful availability of Impala granite..

CMM Machine Structure. The CMM Frame comprises of a 3 Axis device with a CMM Probe mounted at the end of the Z Ram. The Touch Probe is a patented device with a dominant supplier Renishaw who supply the entire market CMM Probes market. Its TP6 and TP2 Touch-Probes are the most widely used by CMM Users. The TP-2 and TP-6 Probes have dominated the CMM market originally being mounted to the CMM with the PH6 adapter. The Motorized Probe Head first appeared in the early 80′s providing an Articulated Probe Head in a Motorized Probe Head form and was called the PH9. To the PH-9 was later added a PH9A which had an Auto Joint to allow an Automatic Probe Changer to be added to a CMM to allow CMM Automation. Later the PH10M was launched allowing longer Extension Bars such as the PAA1, PAA2 and PAA3 to be added and allowing access to deep bores. The P.H.9 and PH-9A are both controlled by the PH9C Controller while the PH10 utilizes the PH10C Controller. The PH9 and PH9A were discontinued during 2000 and replaced by the PH10T or the PH10M. All Renishaw Measuring Probes and Manual Probes and Motorized Probe Heads are very reliable, however in the event of a failure a Repair by Exchange program called RBE is available to keep the CMM Measuring minimizing CMM Downtime.

CMM Styli. The extensive range of Renishaw Probes include the Manual Indexing Heads whose nomenclature include MIP, MIH and MH20i and the additional Motorized Probe called PH50 although this Probe Head with its integral Measuring Probe was not very popular and has been discontinued. The tool used to measure on a CMM is actually the CMM Stylus, the CMM Styli comprises a steel or ceramic shank on which is mounted a synthetic Ruby Ball. The Styli or Stylus comes in various diameters to allow access to features under measurement. Renishaw Styli are extensive in range and also Specialized Styli can be designed and produced.

Renishaw has entered the CMM Scanning Probe market with the SP600, SP25 and fixed head SP80. The SP600 was originally developed for the Renishaw Cyclone Scanning CMM. The Renishaw SP25 and the SP80 probes are designed to turn a traditional Touch CMM into a Scanning CMM and challenge Zeiss Scanning CMMs since the Renishaw solution has nthe added advantage of the PH10 dexterity and utilise new technology with less moving parts and improved performances. Renishaw has also launched revolutionary 5 axis probing technology in the form of the REVO 5 axis scanning probe head which allows incredible new functionality and productivity on a CMM to be realised. The REVO head requires use of the Renishaw UCC Universal CMM Controller and for this reason many OEM’s have resisted the marketing of the REVO probe that mandates the removal of their CMM controller from the provided measuring system. In addition to the REVO Scanning System Renishw has launched the PH20 5 axis measuring probe head which like the REVO offers infinite head positioning. The Renishaw PH20 also uses the Renishaw UCC controller and again many CMM OEM’s has resisted to date offering this head to market. The PH20 is a touch trigger probe head only offering no scanning.

A qualified CMM Technician should perform CMM Installation. In addition CMM Accuracy needs to be verified periodically; the typical CMM Calibration interval is 12 months. The debate of CMM-Calibration versus CMM-Verification rages on however what is important is the Accreditation of the CMM Service Group. A2LA Accreditation and L-A-B Accreditation are the most common CMM Accreditation Agencies in the U.S. for 3rd Party CMM Service Organization many of whom Calibrate CMM's to the B89 or CMMA Specifications. ICMM Service and CMM Repair can be performed by the CMM OEM or by an Independent CMM Service Company although CMM Breakdowns are fortunately not too frequent. International standards under the ISO umbrella have also recently been published including ISO 10360 CMM Accuracy Standard.

The vast majority of CMM Structure uses Air Bearings and as a consequence no wear to the bearing ways occur during CMM Use and as a consequence the CMM Mechanics do not wear out. A CMM Retrofit or CMM Upgrade has become common practice with a new CMM Controller and CMM-Software being applied. The application of a CMM-Retrofit or CMM-Upgrade to an existing CMM allows current technology to be added to an older frame saving considerable money over purchasing a New CMM. A Pre-Owned CMM or Used CMM have also become popular for the budget conscience, some electing to immediately upgrade their Used-CMM with new CMM-Software while other choose to use the original CMM Software. CMM Training is vital for a new CMM Operator to become proficient in CMM Programming and CMM Inspection, CMM Retrofits allows the CMM Operators to attend a CMM Training Class while finding training on older CMM Software Systems can prove more difficult.

Many Inspection Companies have set up using CMM's for Contract Measurement and Contact Inspection. Inspection Service Companies measure customer parts and supply Inspection Data accredited through an Accreditation Organisation such as A2LA. CMM Inspection is now the most common means for the 3D Measurement of manufactured parts. In addition Inspection Houses perform Reverse Engineering, Digitizing and Surfacing for prototype parts. While CMMs are constrained for use in the Inspection Lab the Portable Arm CMM such as Romer and Faro allow for On-Site Inspection to be performed.

The Mobile CMM and Portable CMM device has made large inroads into the market in past years Faro have a competent CAM2 Software that integrates CAD Measurement to the Arm CMM while Romer (also known as Cimcore) use Delcam Software. Laser Trackers from Leica, API and SMX have eroded the manual Horizontal Arm CMM market. Romer, Simcore and Romer France were all acquired by Hexagon Metrology over past years and Hexagon is now a dominant portable arm CMM supplier.

Many other CMM Software companies developing Metrology Software have sprung up in the market. ATT who develop CAPPS and Edges was a pioneer of CAD Metrology; Entelegence Software Solutions is the name given to the development group developing Virtual DMIS, Metrologic of France develops the Metrolog Product. OpenDMIS has become a popular software in USA while the same product is marketed in China under the RationalDMIS name and is developed by External Array. All products are capable of Prismatic Geometrical Inspection as well as Curves & Surfaces.

Contact Programming of CMMs is an additional CMM Service being performed by companies and other Contract CMM Service organizations. Creation of CMM Programs either using the Customer CMM or Off-Line CMM Programming using DMIS, CMM Programming Language or using CAD files. Several Off-Line CMM Programming Software Modules exist that allow for the importation of CAD models and the Virtual Programming of CMM's; available packages include Silma, Delmia, Deneb, Technomatix Robcad and Virtual DMIS. Contract CMM Programmers exist all over the country that specializes in particular CMM OEM Software.

Various CMM User Groups and CMM Chat Rooms appear on the web. PC DMIS, PC-DMIS, Virtual-DMIS and MM4 all have active sites while CMM World and CMM Talk were the most active generic CMM Chat Rooms although both have declined in use as OEMs have developed their own sites. CMM Users, CMM Operators and CMM Programmers have started becoming active in these new era CMM Forums. These CMM Activities also post CMM Positions and CMM Vacancies. CMMs For Sale and To Buy CMM Forums

also exist.

Apart from the CMM training Classes operated by CMM Suppliers very little CMM Training is available and no National CMM Certification of CMM Operators has yet been established. Many Technical Colleges do run Metrology Classes and teach CMM Theory as part of their curriculum. CMM Tuition is available through the plethora of CMM Inspection and CMM Programming Companies and in many cases is the only CMM Source for the older CMM Systems. CMM Classes can be found on CMM Software, Coordinate Metrology Theory, DMIS Training for CMM Techs. Metrology 101 and CMM’s 101 does not exist as yet.

The sale of New CMM Products is very competitive. CMM Performance is compared by CMM Buyers as part of the CMM Purchase process, most insist on a CMM Demonstration being performed on the customer part to test both CMM Ease of Use and CMM Functionality and CMM Performance Verification. Most CMM Buyers compare on average 5 CMM Companies or CMM Distributors.

In addition to the Contact Probe CMM the Video CMM has become popular; few CMM Vendors had manufacture both Types of CMM but recently this trend has changes and today Mitutoyo, Hexagon and Zeiss offer both contact and non contact CMM solutions and products. The Multi-Sensor CMM with a combination of touch and video has become very popular and the trend is expected to continue.

Trade Journals cover both CMM New Products and CMM Application Stories on a regular basis and various CMM Buyer Guides are published annually to summarize the CMM Industry for potential CMM Buyers. In addition Quality Exhibition has become a CMM Showcase which attracts CMM Buyers, CMM Dealers, CMM Representatives, CMM OEM, CMM Users, CMM Programmers, CMM Operators, CMM Technicians, CMM Staff.

A common CMM Programming Language has been created called DMIS (Dimensional Measurement Interface Standard) has started to eradicate CMM vendor specific programming languages. Native DMIS whereby DMIS is the CMM Language has come of age and software like Virtual DMIS take full advantage of this function. Other CMM Software products like PC DMIS use DMIS in a translated form.

Scanning Sensors using Laser Scanning technology have also started being integrated to the Coordinate Measuring Device. Metris now Nikon, Perceptron, Hexagon, Laser Design and Steinbichler all offer solutions.

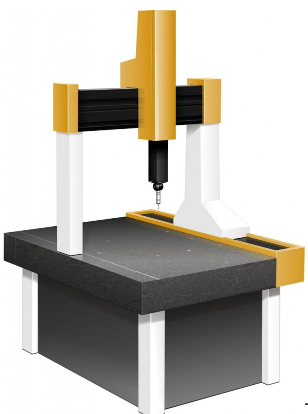
The future of the CMM is difficult to predict many are suggesting that CMM Technology will become obsolete in the coming decade. CMM Products however continue to dominate the manufacturing inspection arena and unless a major technological innovation occurs the CMM will remain the focal point of the Quality Laboratory. The current trend is to move CMM Measurements to the production Floor and many new designs have come to market in recent years specifically aimed at this application. Flexible Gaging is the current trend and customers require these systems to be supplied as CMM Turnkey Projects. CMM have also gotten faster over the past decade although few customers need speed to be achieved at the expense of CMM Accuracy.

Renishaw has recently launched its Equator flexible shop-floor gauge system. The unique structure uses the SP25 scanning probe, UCC controller and modus software to inspect using 3d CMM techniques. The machines uses a golden part for calibration and all other parts are measured against the nominal data of the golden part. The CMM price is very attractive and will challenge the use of traditional CMM machines as a shop-floor flexible gauge.

The predicted of customers selecting CMM Hardware independent of CMM Software has not yet occurred. The Common CMM Driver project called I++ was a major initiative of CMM users to force CMM vendors to open CMM Controller architecture. The Renishaw UCC CMM Controller uses the I++ protocol and allows plug and play metrology software. This open operability will was expected to have a significant influence on the market; the latest Renishaw Scanning Sensor and Infinite Index Heads are not available for integration by the OEM into their own controllers.

With such a plethora of CMM manufacturers to choose from its doubtful that all will survive in the future; in addition the further industry consolidation will reduce the supply base. There is no doubt that Mitutoyo, Hexagon and Zeiss will be the major CMM suppliers over the long term; will a Chinese company emerge and join the Big 3 CMM suppliers and will Renishaw take the final step and enter the market directly in coming years.

CMM Structure Design Evolution



The Coordinate Measuring Machine first appeared at the international machine tool show in Paris in 1959, exhibited by the British company Ferranti, who had also launched the first commercially available general purpose computer some years earlier.

Over the years various configurations of CMM have been developed; the most popular one being the bridge design that today accounts for over 90% of the CMM market. The bridge structure of the machine rests on top of a granite surface plate and usually the X, Y, Z structure glides on friction free air bearings.

CMM Function

The CMM mechanical structure is a carrier for the measuring sensor with the function of reporting the location of the measured points on the part under inspection. The CMM coordinate system is produced using linear scales attached to the CMM structure. A perfect CMM structure, with no intrinsic errors, would result in the exact location of the probe points being reported. The perfect mechanical structure does not exist and there are many sources of error contributing to the small deviation between the scale readings and the actual sensor position. This is identified as the CMM Measuring Error. Not only is the precision of the CMM structure critical but also the actual mounting of the measuring scales to the structure since it's the scales that encode the actual sensor position. As an example a CMM with a separate and independent X, Y Z encoding system would result in a sensor position being recorded independently of structure errors.

The bridge structure of the CMM was manufactured in the early years from granite, cast iron or steel.

Granite

Granite has long been used in the metrology world in the form of surface plates, straight edges and squares. Granite has a very low absorption rate of thermal changes and a low coefficient of expansion. It is also heavy and unpredictable as a material, due to its natural occurrence, and its low modulus of elasticity can cause fractures if a CMM crash occurs. Simple parts like rectangular beams can be manufactured with relative ease from granite while complex geometry designs are much more problematic. The use of granite is therefore a design constraint when developing a modern coordinate measuring machine design.

Cast Iron

Again cast iron has been traditionally used for surface plates in the metrology world due to its relatively low coefficient of expansion. Since any parts are produced using the casting process each CMM model and size would require different size parts and thus each requires a separate casting. The multiple machine sizes offered by the CMM industry has rendered cast-iron impracticable other than for large table on extra-large CMM units.

Steel

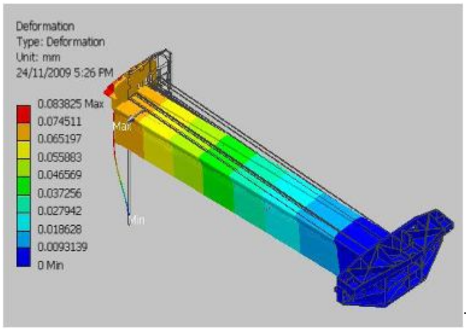
While not the perfect metrology material steel allows mass production techniques to be introduced to the CMM manufacturing process through the use of machined weldments; steel allowed the CMM industry to move away from its hand craftsmanship production techniques. All of the major CMM suppliers manufactured steel CMM structures in the 1980's as production volumes gained pace. The granite CMM in the 1980's and 90's was relegated to being produced by only the very small localised CMM manufacturers who had not the investment or production volumes to move to steel structures. Almost all of these are no longer in business. Steel fabrication are still in use today on large Gantry style CMM's.

The early Coordinate Measuring Machines were hand crafted with mechanical precision. Many CMM builders offered two accuracy grades; the enhanced accuracy grade being achieved with more selective assembly and overall care in the assembly process. Many of these machines lost their precision over time as wear occurred in the system drives and other critical components.

The market demanded more accuracy from the CMM over the years since manufacturing tolerances have been reduced in order to satisfy improvements in product reliability and improved performance together with new design concepts. Improved accuracy, improved speed, lower costs and the ability to relax the installation environment were the demands heard by the industry coming from CMM customers.

The use of intrinsic error identification and their collection with subsequent error mapping using mathematical algorithms resident on the CMM computer were initially developed and utilised to enhance the accuracy of the mechanically precise CMM. Error mapping of a CMM involves the mathematical definition of the constant or predictable errors and their correction using software algorithms such that a perfect CMM structure is simulated and the adjusted X, Y, Z position of the sensor points reported.

The New Generation of CMM Design



The introduction of CAD and FEA allowed designers to start understanding the behavior of CMM structures. Computerized modeling allows the CMM designers to optimize their design to remove unnecessary mass and strengthen parts in critical areas to minimize deformation etc. The ability to strengthen a part in a localized area while reducing overall mass led to the consideration of emerging new materials such as alloys in the CMM design.

These alloys provide a lighter, stiffer structure while at the same time improving reaction to, and dispersion of, temperature changes and actually result in less deformation of the CMM structure than that experienced by the slowly reacting structures manufactured from granite or cast-iron.

The construction of the CMM structure from new high technology alloys materials is proven to provide a lighter, stiffer structure while at the same time improving reaction to, and dispersion of, temperature changes, when the CMM is installed in a less than perfect environment, and actually results in less deformation of the CMM structure than that experienced by the slowly reacting granite and cast-iron structures. Integrated with the alloy structures are new generation measuring scales, such as the Renishaw *'Fastrack' system,* that locates the scale in a substrate mounted to the CMM structure and are free and independent of any CMM structural movements increasing dramatically CMM accuracy even when installed in non-perfect environments.

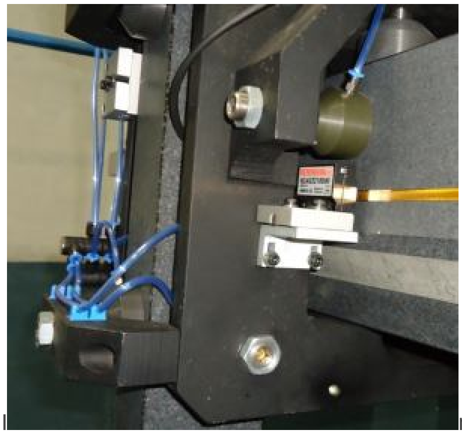
An aluminium alloy CMM structure is lighter and has an improved reaction to thermal changes resulting in less linear and torsional structural deformation and integrated with the free-floating measuring scales with thermal compensation provides the ideal platform for the next generation coordinate measuring machine.

The principle CMM design focus for a modern CMM include the moving mass, dynamics and thermal properties of the CMM frame. Using alloy components for the frame reduces the power required to accelerate the frame when in motion resulting in the use less of smaller less powerful motors creating less heat and also causing less structural inertia distortions.

Although aluminium alloys have the same specific weight as granite it's not used as a solid block like granite and in addition production processes like extrusion allow for the manufacture of CMM structural elements with thicker material and ribbing located by design to maximise element stiffness.

Granite structures are also less predictable due to the inconsistent material properties of the natural granite product and have their scales rigidly mounted so any granite movement directly affect the scale measuring performance creating inaccuracies. Since the accuracy of the CMM is derived from the scales and not the CMM structure the arguments for the stability of granite are false. They are valid for static granite blocks used as granite plates and straight edges where no measuring scales are involved. In addition granite has a low rate of thermal diffusion meaning that it dissipates any thermal change very slowly and therefore the inaccuracies in the structure remain longer.

The use of a thick granite plate in a CMM design appears to provide the image of great stability. In practise however the use of a thick granite plate has negative implications when the plate is subjected to thermal changes. Because of granite's low thermal conductivity it processes thermal change very slowly resulting in a non-uniform temperature distribution in the plate causing plate bending to occur. Although this bending is only measured in microns since the CMM bridge is riding on the granite plate its sufficient to cause significant measuring errors. For this reason the granite plate of all modern CMM designs have been optimised for thickness to reduce this bending effect and minimise its impact on CMM accuracy while ensuring its thick enough to support specified component weights without distortion.



In addition many older CMM design offer an inconsistent use of materials. For example most granite CMM have the bridge beam support legs produced from steel or aluminium and the X/Z carriage supporting the Z column is manufactured from an aluminium casting for convenience; so much for their granite arguments when they have polluted their own material science arguments!. In addition aluminum air bearings are also used throughout a granite CMM. Look under their covers and see for yourself….

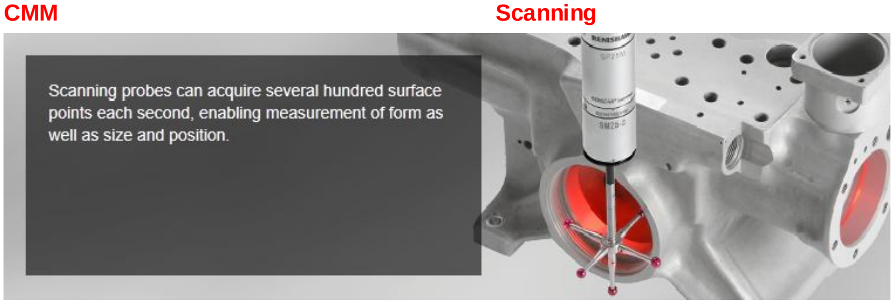
Modern CMM designs use a single material type throughout the entire CMM frame.

Today the largest global CMM manufacturers from USA, Japan, Germany and Italy all incorporate in their modern CMM designs a moving structure produced from aluminum alloy. All have researched the subject independent of each other and reached the identical conclusion. *"Granite is an out-dated material for the moving structure of a CMM".*

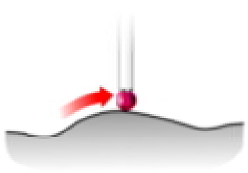
Non linear motion of a Cartesian CMM such as experienced during the scanning process induces accelerations and deceleration forces that can twist and deflect the CMM machine structure; these dynamic deflections can result in measurement errors that increase with measurement speed. In addition the scanning probe deflection force can induce a potential deflection of the CMM Z column. While the modern design alloy CMM is designed for maximum stiffness the upgrade of the Z column to silicon carbide results in an improved scanning performance for the CMM.

The new 5 Axis scanning Technology from Renishaw eliminate these errors since the scanning motion is all contained within the probe head.

CMM Scanning Expained

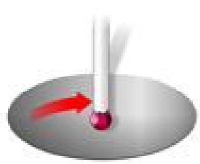


Scanning provides a fast way to capture form and profile data from prismatic or complex components.



While touch-trigger probes gather discrete points on the surface, scanning systems acquire vast quantities of surface data, providing a clearer picture of the form and shape of the workpiece. Scanning is therefore ideal for measurement applications where the form of a feature is a significant element of the overall error budget, or where complex surfaces must be inspected.

Scanning requires a fundamentally different approach to sensor design, machine control and data analysis.



Renishaw scanning probes feature innovative, lightweight passive mechanisms (no motors or locking mechanisms) that exhibit a high natural frequency, making them suitable for high speed scanning. Isolated optical metrology systems measure the deflection of the stylus directly (not via stacked axes within the probe mechanism) for better accuracy and faster dynamic response.

Scanning probes provide a continuous deflection output that can be combined with the machine position to derive the location of the surface. When scanning, the probe stylus tip is brought into contact with the feature and then moved along the surface, gathering data as it moves. Throughout the measurement, it is necessary to keep the deflection of the probe stylus within the measurement range of the probe.

For best results, this demands close integration of the sensor and machine control, as well as sophisticated filtering algorithms to convert the resultant data into useable surface information. Scanning drive algorithms can adapt to the contours of the part, changing the scanning speed to suit the rate of curvature (going faster on flatter surfaces) and adjusting the rate of data capture (taking more data where the surface changes quickly).

5 Axis CMM Measurement

A Measurement Revolution

For more than 30 years, Renishaw has delivered innovations that have been milestones in CMM metrology, from the original touch-trigger probe and motorised indexing head, to repeatable stylus changing and modular scanning systems. Renishaw's 5-axis measurement technology represents the biggest step-change in measurement capability that has ever been introduced, resulting from the biggest research and development program Renishaw has ever undertaken.

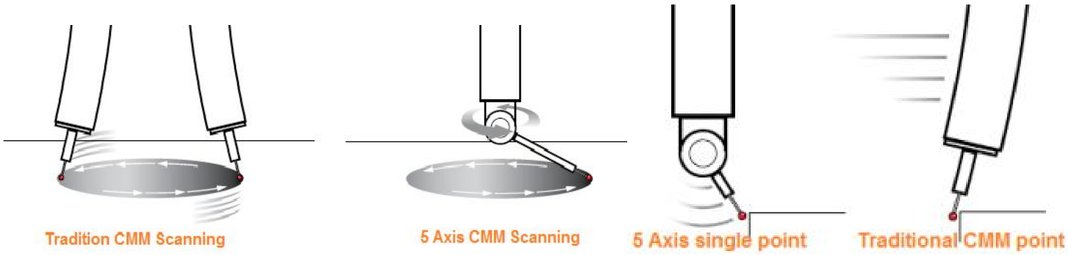
What is 5-axis measurement?

Based on advanced head, sensor and control technology, Renishaw's 5-axis measurement technology delivers unprecedented measuring speed and flexibility, whilst avoiding the speed versus accuracy compromises inherent to conventional techniques. It boosts measurement throughput, minimises lead times and gives manufacturers a more comprehensive appreciation of the quality of their products. Unlike systems based around indexing heads or fixed probes, 5-axis motion enables the stylus to follow a continuous path around complex components without having to leave the surface to change stylus cluster or index the head. Controller algorithms that synchronise CMM and head motion produce an optimal tip path and minimise CMM dynamic errors.

Provides Increased CMM Productivity

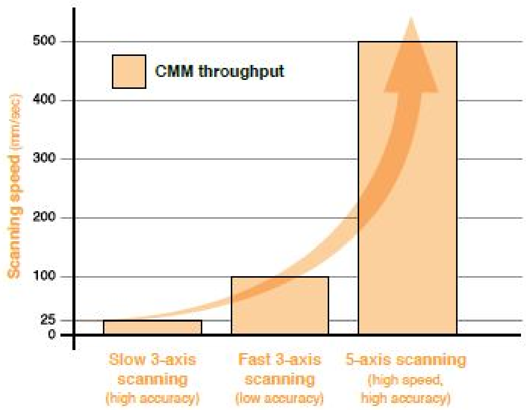
The ultimate scanning speed of a CMM is limited by machine dynamics, typically to between 80 and 150 mm/sec. However, long before we reach this limit, measurement accuracy falls away – often limiting the effective maximum measuring speed to between 10 and 25 mm/sec.

How?



Non linear motion on a Cartesian CMM induces acceleration and deceleration that twist and deflect the machine structure,and these dynamic deflections result in measurement errors that increase with measurement speed and acceleration.To avoid dynamic deflections, Renishaw's 5-axis measurement minimises machine accelerations, whilst moving the stylus very rapidly over the component surface.

Advantages of Renishaw's 5-axis measurement



Renishaw's 5-axis measurement breaks through the dynamic performance barrier by minimising the accelerations and hence the inertial loads on the machine structure. Renishaw's dynamic heads do most of the measurement work, enabling exceptional throughput without compromising accuracy.

Renishaw's unique 5-axis measuring features

Renishaw's 5-axis measurement technology allows you to replicate your current CMM measurement strategies – only much faster and also incorporates new scanning techniques. Bores can be measured using touch points, circular scans or helical scans, whilst data on contoured surfaces and edges can be captured with a sweeping motion of the head. Renishaw's 5-axis measurement technology not only makes new ways of scanning possible, but also allows you to replicate your current measurement strategies, faster than before.

5-axis touch trigger benefits

- ‘Head Touches’ take measurement points faster, with improved accuracy and repeatability
- 5-axis motion eliminates time spent indexing the head
- Infinite positioning capability guarantees optimal feature access minimising stylus changes
- 5-axis simultaneous motion allows larger parts to be measured on the CMM by minimising the space required around the part for head rotation

5-axis scanning benefits

- Simultaneous motion control of 5 axes
- Data gathered ‘on the fly’ whilst the head is moving
- Dynamic 2-axis head provides most of the stylus motion minimizing CMM motion
- Unique tip-sensing technology
- Scanning with 5-axis of simultaneous motion provides unparalleled measurement flexibility