Integrated Information for Improved Quality

Dr Toby Maw

10/10/2017

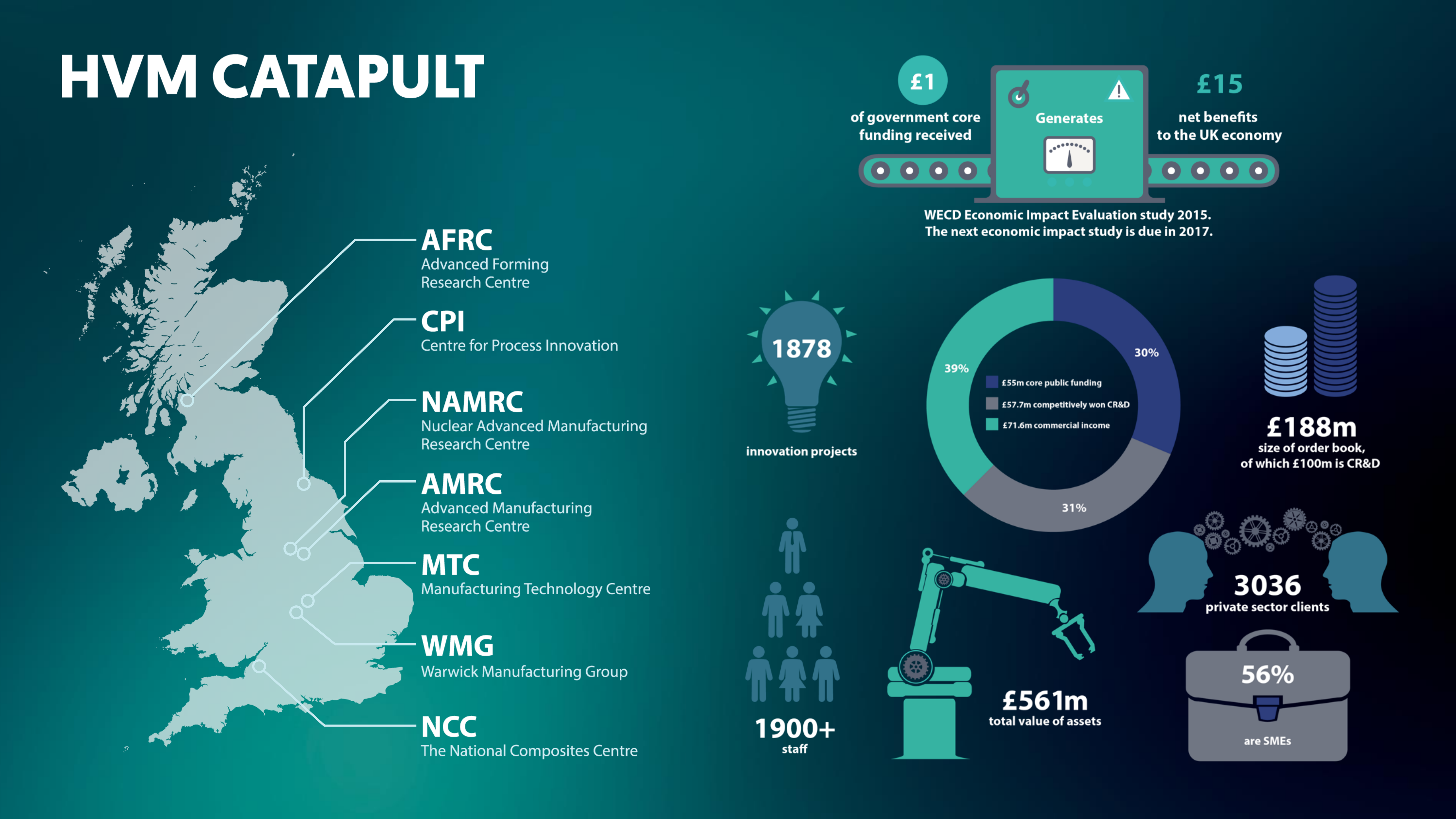
CONTENTS

Manufacturing Technology Centre

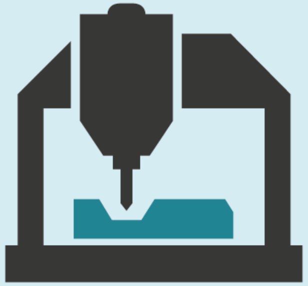
Who are we?

INSPIRING

Great British Manufacturing


HVM CATAPULT
AFRC
Advanced Forming Research Centre
CPI
Centre for Process Innovation
NAMRC
Nuclear Advanced Manufacturing Research Centre
AMRC
Advanced Manufacturing Research Centre
MTC
Manufacturing Technology Centre
WMG
Warwick Manufacturing Group
NCC
The National Composites Centre
£1
of government core funding received
Generates
£15
net benefits to the UK economy
WECD Economic Impact Evaluation study 2015.
The next economic impact study is due in 2017.
1878
innovation projects
30%
39%
31%
£55m core public funding
£57.7m competitively won CR&D
£71.6m commercial income
£188m
size of order book, of which £100m is CR&D
1900+
staff
£561m
total value of assets
3036
private sector clients
56%
are SMEs

INDUSTRY CHALLENGES



You want to make something

- at a lower cost
- better quality
- quicker
- in higher volume
- you've never made before

You want to assemble something to

- minimise reject rate
- improve reliability
- improve consistency
- reduce waste
- reduce errors

You want to use data more effectively for

- improved design
- better quality
- efficient logistics
- new business models

End Users

Standards Agencies

Software Providers

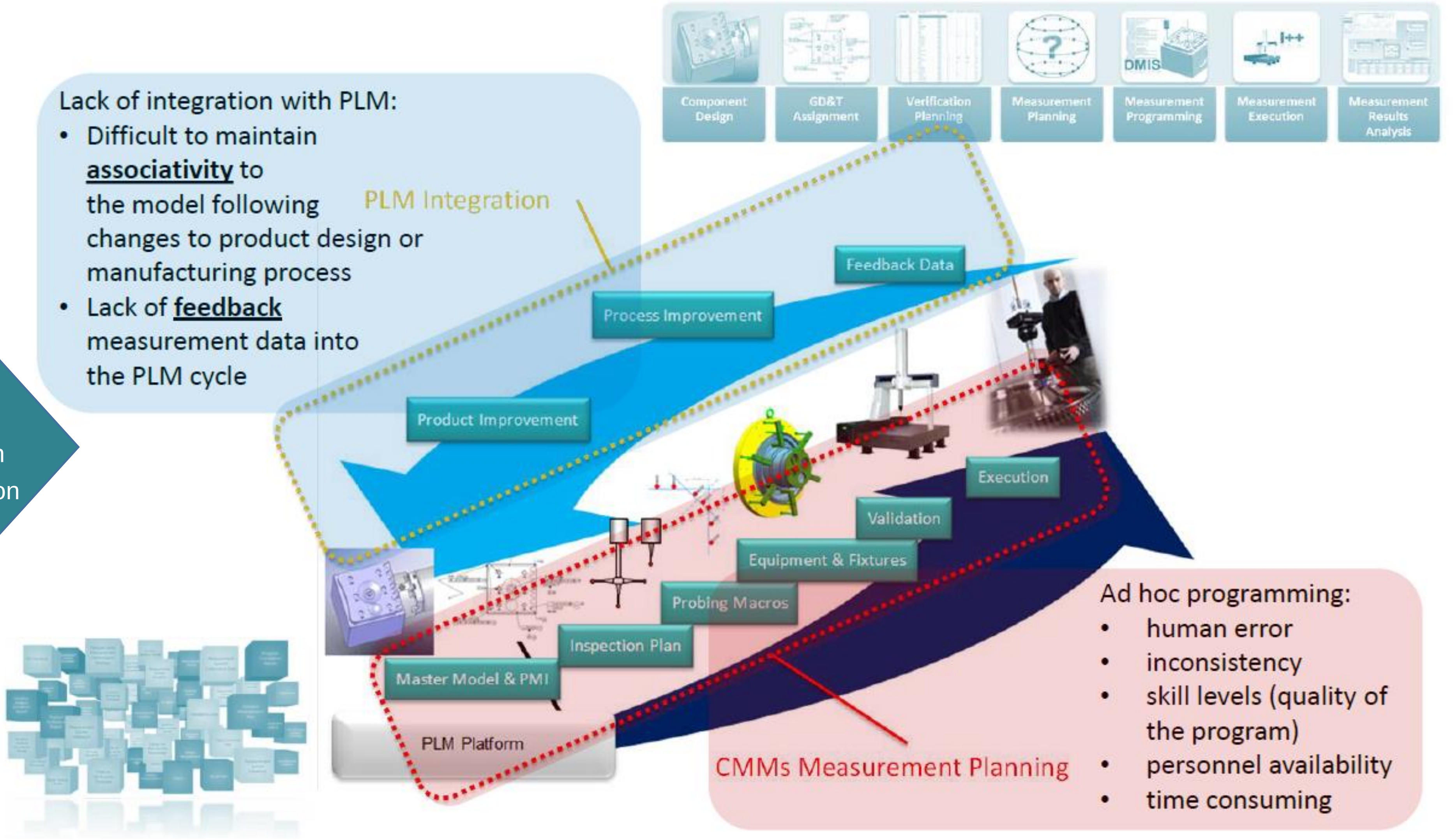
Thank You

Consortium Members			**Collaborators**
ATS	GE Power	Metrosage	DMSC
AWE	GKN Aerospace	Nikon Metrology	NIST
BAE Systems	Hexagon Manufacturing Intelligence	Parker Aerospace	NPL
BOC	iBASEt	Renishaw	Origin Intl.
Capvidia	IPI Solutions	Rolls-Royce	NCC
Controls & Data Services	Kotem Technologies	Sandvik Coromant	
DMG Mori	Mahr	Siemens PLM	
Doncasters		Theorem	

BACKGROUND

Computer Aided Inspection and Quality - Current State

- Product design:
  - 2D drawings
- Inspection planning:
  - Drawing interpretation
  - Feature definition
  - Ballooning
  - Bill of Characteristics
  - Measurement strategy selection
  - Measurement resource allocation
- Inspection program authoring
- Feature evaluation
- Results analysis
- Sentencing

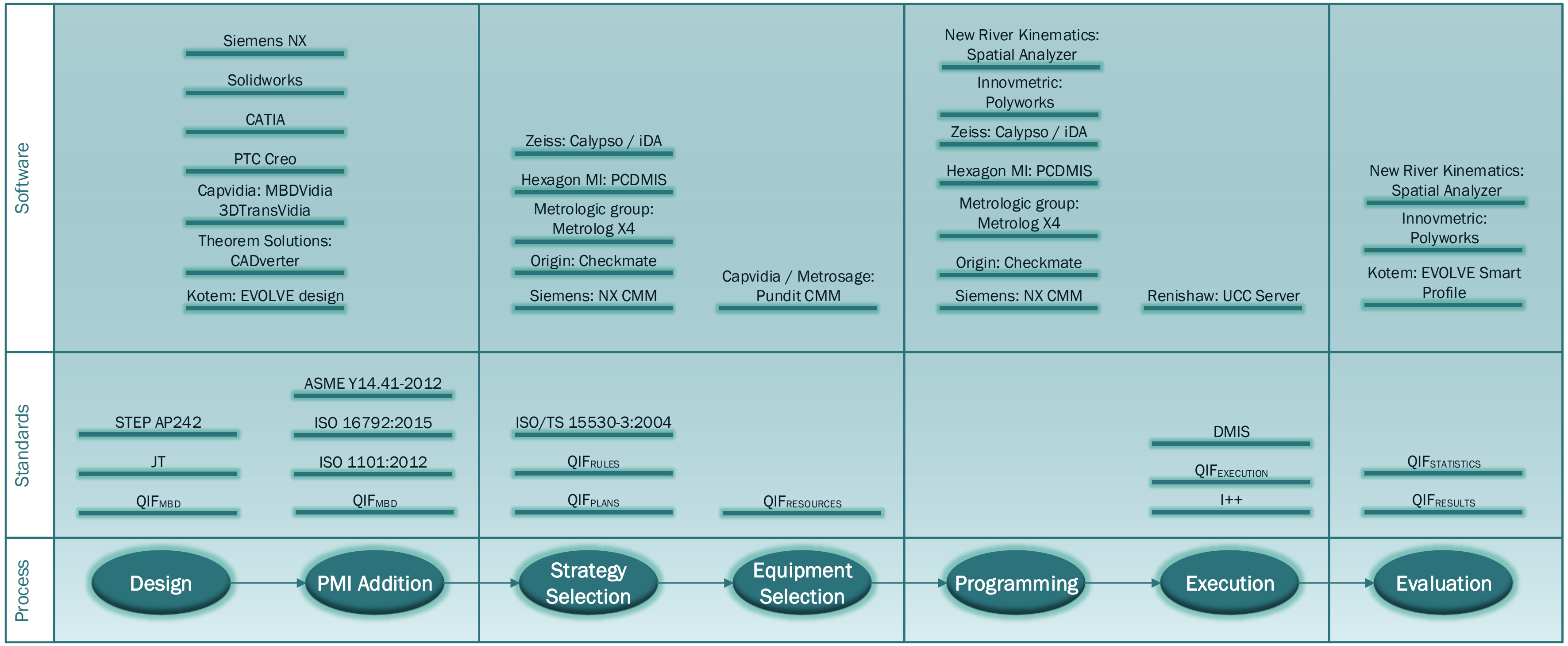


Computer Aided Inspection and Quality

Emerging Technologies

- There are many standards and software tools currently in development across the industry that have the potential to transform and simplify the current process chain.

  - Semantic PMI
  - Bill of Characteristics
  - Uncertainty Simulation
  - Automatic Programming
  - Automatic Evaluation
  - Results Visualisation
  - Consistent Data Type

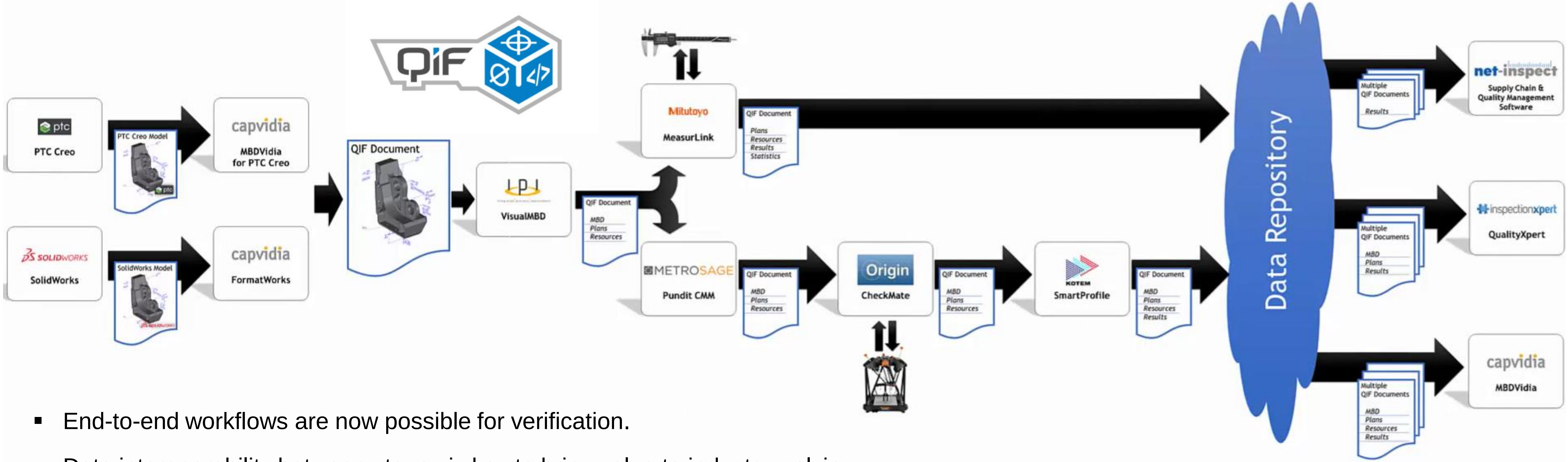


List of standards and software covering the digital measurement planning workflow. This list is not exhaustive.

- The whole process chain is covered for each individual process by multiple software.

Computer Aided Inspection and Quality

Emerging Technologies



Example workflow showing how CAD with PMI can be taken through the full measurement planning and execution process using digital tools for simple components as presented at IMTS 2016.
Video available at https://vimeo.com/182244101

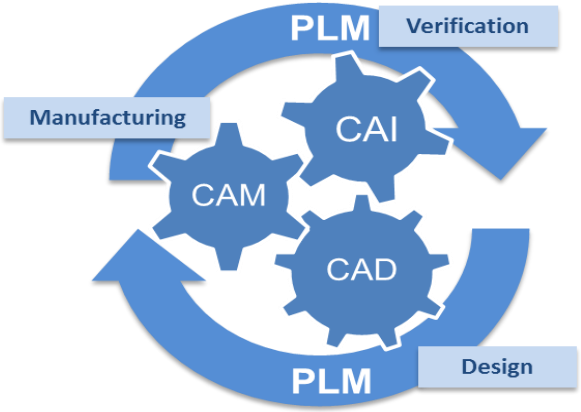
- End-to-end workflows are now possible for verification.
- Data interoperability between stages is key to bring value to industry, solving:
  - Traceability issues;
  - Version control;
  - Integration with existing management systems.
- CAD with PMI associatively linking tolerance information to design features enables design information to be passed downstream to all other process steps in the chain.

The Big Picture

Integrated Information for Improved Quality

Component verification

Gather and analyse data from across the whole process chain.

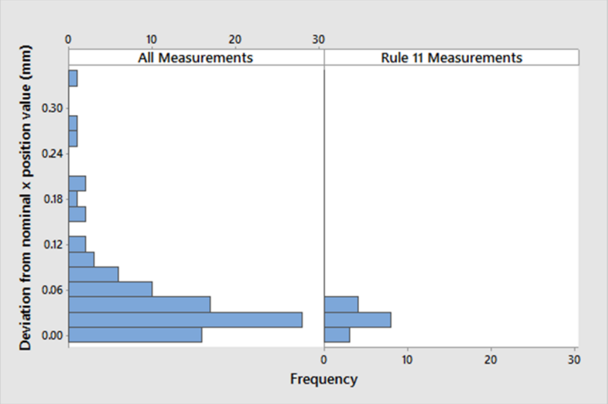


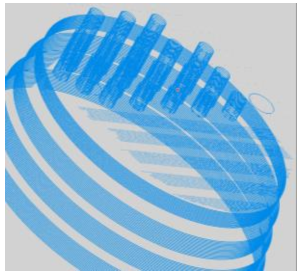
Intelligent Process Control	Adaptive Inspection Planning	Root Cause Analysis
Optimisation of production quality by altering input machining parameters.	Drive adaptive inspection plans by filtering out features within process capability.	Aid root cause analysis by keeping traceability of all data to an instance of an authority model.
Increase component quality, reducing scrap and rework.	Reduce cycle times and reduce load on measurement equipment.	Expose why something failed, not just flag that there was an issue for corrective action.

CASE STUDY

Data Analytics Validation

- Rules linking final part quality of a test batch to machining parameters of production were tuned to provide key process variables to improve future builds.
- Reduced standard deviation of sample deviation demonstrating improved quality.





- Data analytics was labour intensive.
- Lack of interoperability of data formats.

Analysis of the manufacturing signature using data mining

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Manufacturing signature
Machining
Fourier series
Forsythe polynomials
Legendre polynomials
Orthogonal transformation

A B S T R A C T

The use of data mining within manufacturing is a relatively modern application. Data mining can be used to find underlying links between the machining conditions, and parameters, and the final form of the part. Part of this procedure includes defining the form of the part, known as the manufacturing signature, which stems from all steps in the manufacturing process. In this paper, two potential definitions for the manufacturing signature of cylindrical objects are generated in terms of an analytical basis. The first description uses a simple Fourier description (known as lobing) and the second consists of a fully orthonormal description in terms of Forsythe polynomials and Fourier coefficients. Principal Component Analysis (PCA) is also partially used to investigate the underlying structure of the cylinders and investigate the connection between the analytical description and PCA. Experiments were carried out, machining thirty components under different manufacturing conditions (such as coolant pressure, tool length etc.). Data mining was then carried out on the process parameters, and either the amount of a given type of lobing or the classification of the cylinder in terms of the maximal lobing. The input to data mining for our case is either a numeric answer or a classification, which motivates the use of a simplified description. The use of PCA on this data set indicates a fundamental issue stemming from subsets of "similar" data which means dimensionality reduction is not possible in the usual way. The use of the analytical basis suggests a new sampling strategy to be used on certain geometries utilising Gauss-Legendre quadrature.

R.J. Mason, M. Mostafizur Rahman, T.M.M. Maw, Analysis of the manufacturing signature using data mining, Precision Eng., 47, 292-302, (2017)

Prediction of part quality using regression tree learning

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(Dated: XX:XX:XXXX)

Abstract— **In manufacturing processes there is a large amount of data generated which when captured and analysed effectively can be used to improve the performance of the process. Recently there has been interest in using data mining techniques to identify associative links between machining conditions and the final part quality. However many of these techniques require classification of parts as passing or failing a tolerance, and often have difficulties building a realistic model as there is usually a strong class imbalance towards parts passing an inspection in manufacturing. This paper presents the results of an experiment in which regression tree learning, a method which uses raw measurement values rather than classifications, is used to generate rules linking final part quality to manufacturing parameters in CNC machining. A regression tree was generated from an initial production run of components in which the machining parameters were varied between features and parts, and rules identified which when followed resulted in reduced manufacturing errors in drilled holes. A further set of test components was then produced and measured which verified that features which followed these rules had, on average, a reduced deviation from nominal position and diameter. It is proposed that having been validated in this work, such a methodology would be useful when developing new products or processes for optimizing the final part quality.**

To be submitted for publication this autumn.

CASE STUDY

Data Integration Experiment

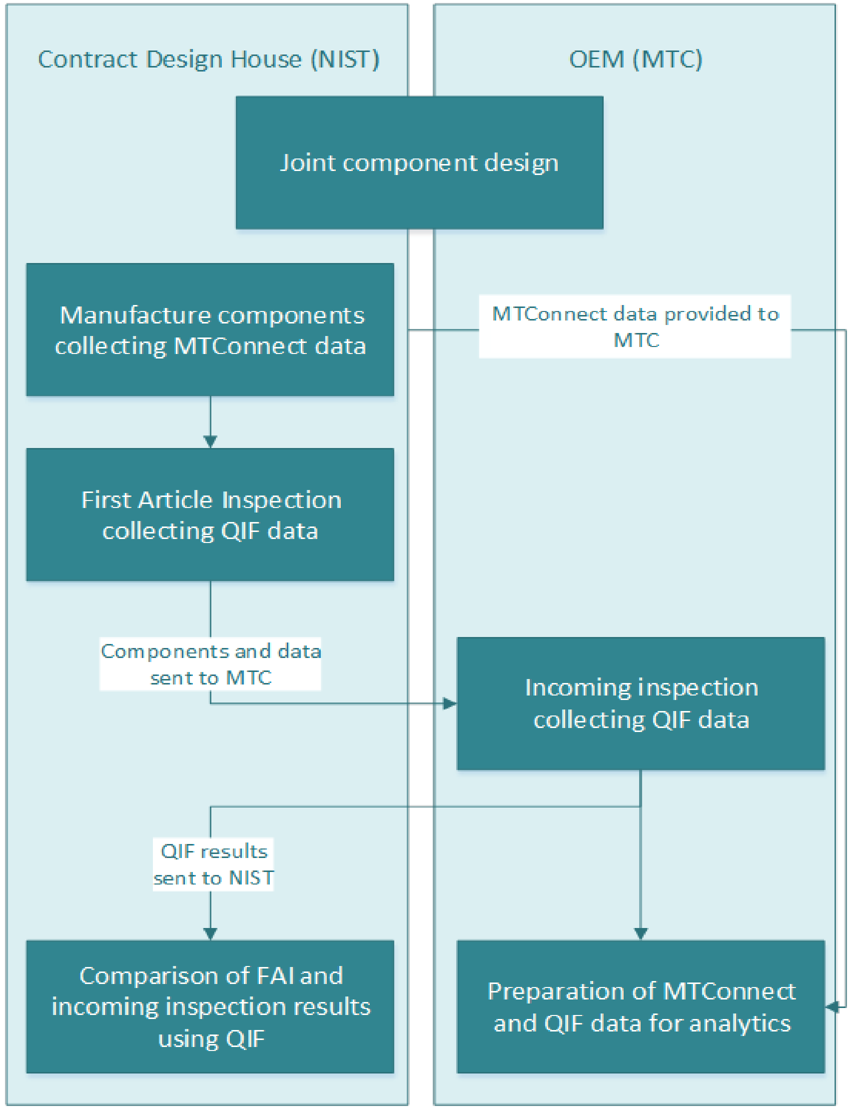
- Collaboration with NIST

- Objectives:

  Investigate data standards for manufacturing process control;

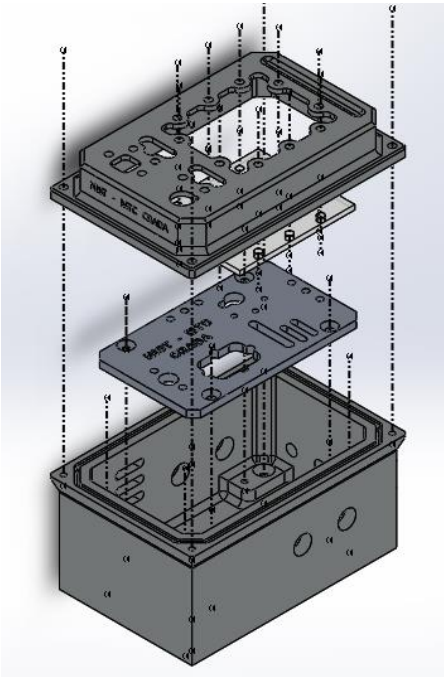
  Investigate techniques for manipulation of data standards;

  Identify capabilities and gaps of integrated data interoperability.

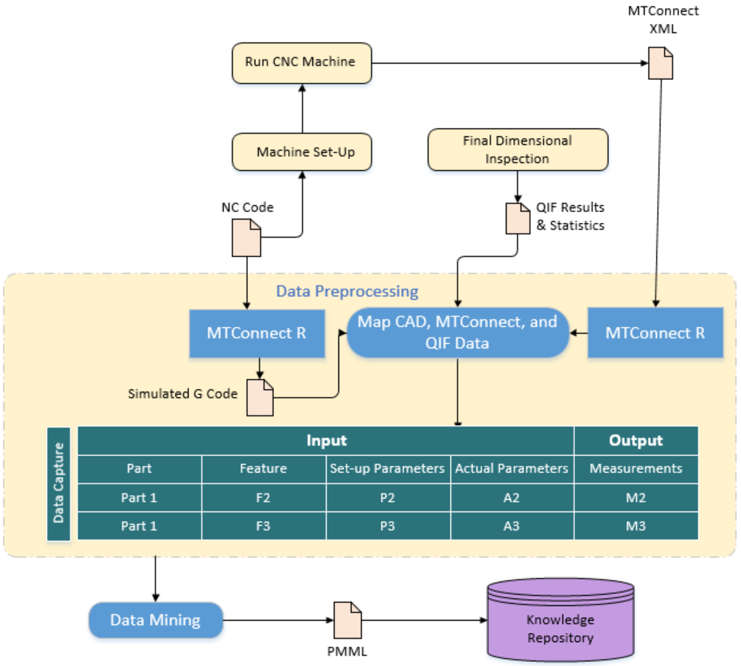


CASE STUDY

Data Integration Experiment



Test assembly produced for data integration experiment.



Experiment data flow illustrating how manufacturing and inspection data must be mapped using feature ID as a reference.

Full details to be published in a joint paper between MTC and NIST this summer.

Experiment Results

- Automatic analytics is key to accessing the benefits.
- Data interoperability between processes is critical.
- Persistent IDs are required that make all data traceable to the authority CAD model through all process steps.
- This would have to include CAM, CAD and CAIQ data forms.

This is not easy!!!

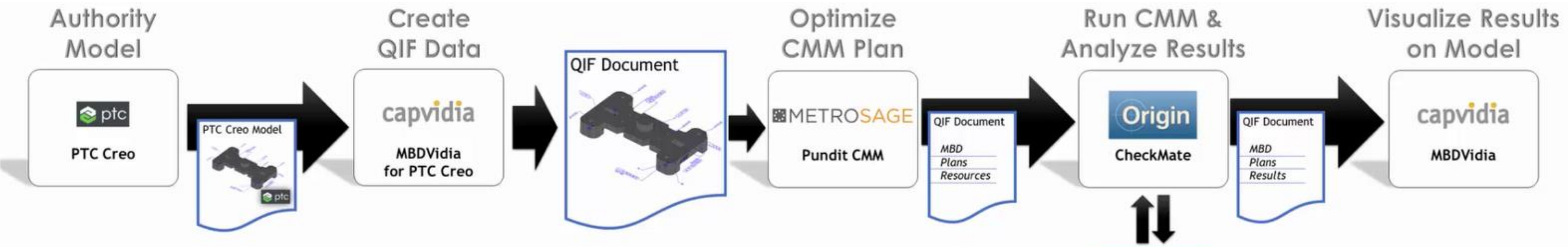
Adoption of data standards such as QIF that have the architecture to apply to all process stages.

– or –

As mentioned earlier, software vendors can develop their own methods to communicate to each other.

Conclusions

Integrated Information for Improved Quality



Example workflow showing how CAD with PMI can be taken through the full measurement planning and execution process using digital tools for simple components as presented at IMTS 2016.

- End-to-end workflows are now possible for verification.
- Such workflows can be used to get industry engaged such that they can provide the drive for vendors to adopt solutions to interoperability problems.
- Dramatic benefits can be gained by further integrating information through manufacturing and management processes.
- Standards and interoperability are the keys to unlocking the benefits from analytics.

Once end users become aware of the potential benefits, software vendors will be compelled to adopt the standards and drive the industry forward.

Thank you for listening!

Any questions?

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