

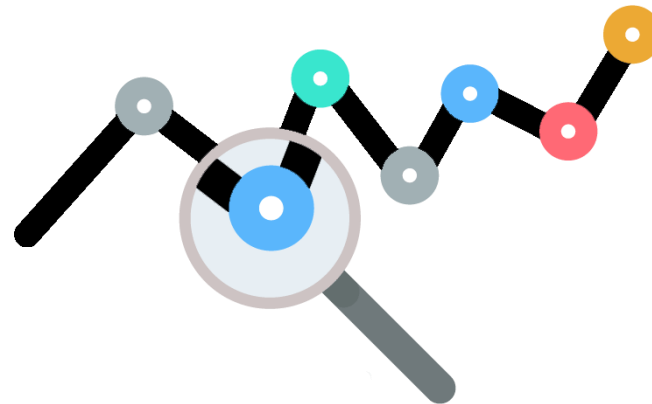
## CU 36: Coordinating the AM Process (Pilot)

## TOPIC: Traceability and Control of Documentation

Prepared by: Aneta Chrostek-Mroz

# Topics covered include...

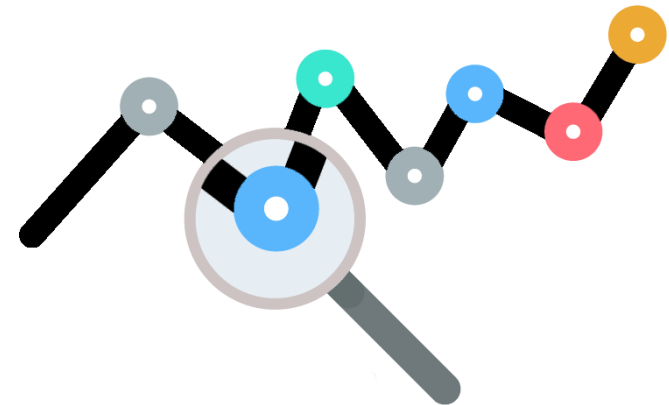
- What is traceability and why is it important
- Definition of traceability
- Traceability in AM
- AM process chain
  - Focus on feedstock
  - Part production
- Traceability check list



# What is Traceability?

“ability to trace all processes from procurement of raw materials to production, supply, use, maintenance and disposal” - **when, where** and **how**

- Critical part of an effective quality management system
- Collecting information vital
- Evidence of effective traceability underpins certification



# Traceability for AM: Manufacturing History

Any controlled manufacture process would have been developed through experimental workings. The found process would be documented as procedures/ specifications as per topic 6 AMPS. This should form the basis of manufacturing history where by known steps were carried out with the details of **how** and **when** and **why** they were carried out.

The process chain must be defined and recorded as per specification so it can be repeated for volume production but also to allow approval of production with known history and manufacturing information – ***any anomalies can then be identified that could deem scrap or warrant further inspection to approve***

Additive Manufacture provides the opportunity to gain significant amount of manufacturing information – ***you get information for each component layer processed in AM***

***BUT***

***AM also poses the challenges on dealing with large amounts of data sets (Terabytes from single process run)***

# Definition of Traceability: ISO 9001

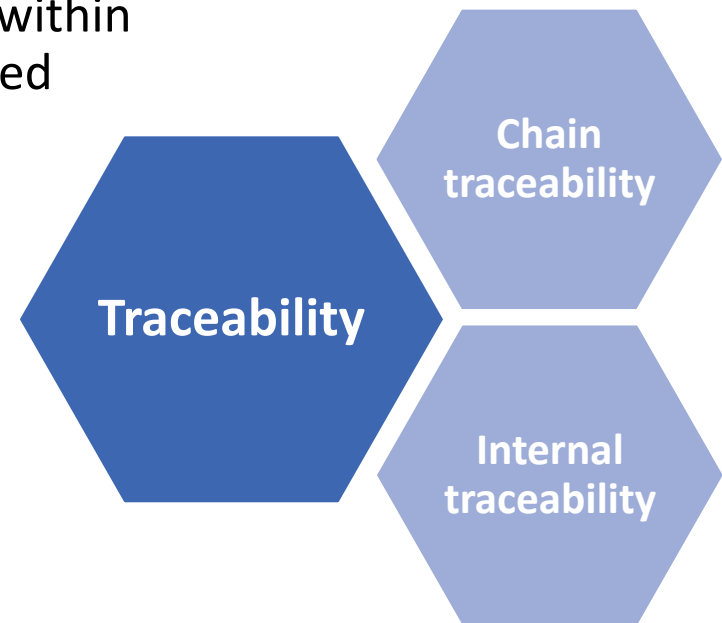
- The quality management system of the International Organization for Standardization (ISO) is generally called the ISO 9000 series or ISO 9000 family and ISO 9001 is the most important standard in this family. A quality management system (QMS) is defined as "part of a management system intended to lead and manage an organization regarding quality."
- ISO 9001 is an international standard based on the essence extracted from many successful cases regarding business improvement. Its purpose is to maximize profits by promoting business based on consistent rules concerning not only manufacturing processes or products, but also throughout the business from purchase to manufacturing, shipment, and service. We can say that it is the best guideline for improving routine work by eliminating problems such as inefficient procedures or repeated mistakes. By obtaining ISO 9001 certification, the company can also achieve social credibility and increase the trust of customers.



# What is Traceability in Additive Manufacturing

**Chain traceability** – Movement of products in multiple processes (between different departments e.g. Additive Manufacturing , Materials Characterisation Lab, Metrology, Metallurgy)

**Internal traceability** – Movement of products within a single process that can be monitored (a limited specific area in a whole process, e.g. Additive Manufacturing)



# Traceability for AM

- For the AM process and all stages of a process from feedstock procurement to production of AM parts, post processing, part testing, distribution or disposal need to be traceable.
- Lack of traceability can result in an increase in error and non-conformance
- For an AM facility both chain and internal traceability need to be considered

# Importance of Traceability for AM

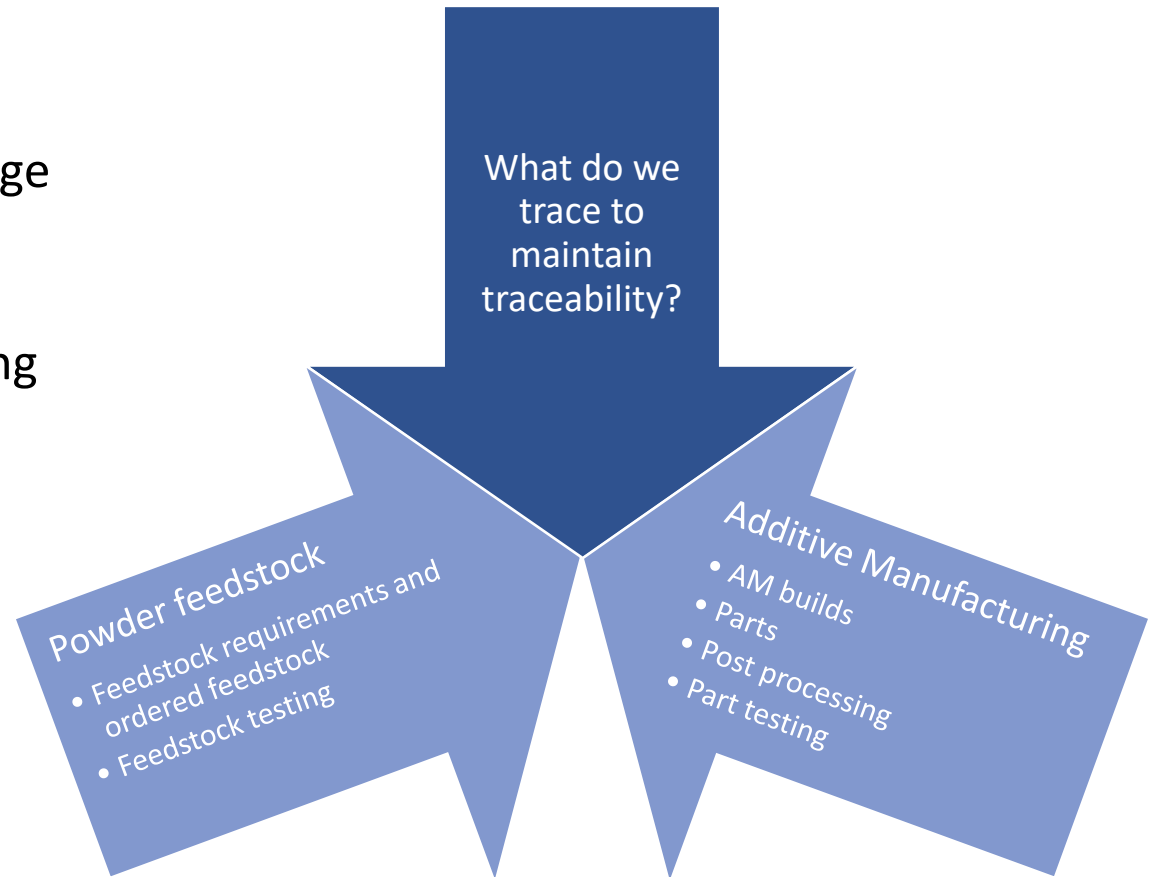
- Error and non-conformance reduction
- **Component failure investigation**
- Cost saving
- Quality improvement
- Customer confidence
- Cost saving
- Business protection
- Reputation





# Chain Traceability in Additive Manufacturing

- Feedstock procurement
- Feedstock receipt and storage
- Feedstock testing
- Production & post processing



# Tools Allowing Traceability in AM

## Documentation of intended work

- Templates
- Processes

## Record Keeping of what have been done

- Completed forms
- Record sheets
- Drawings
- Parts
- Samples
- Machine logs
- Data

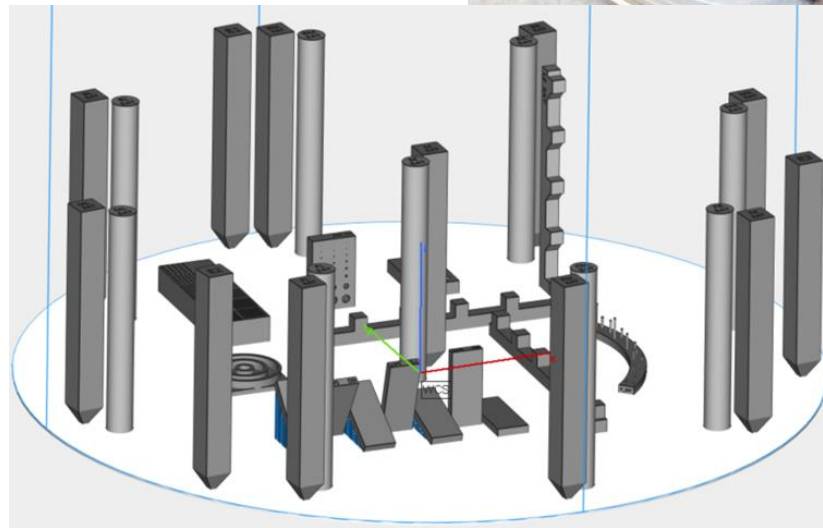
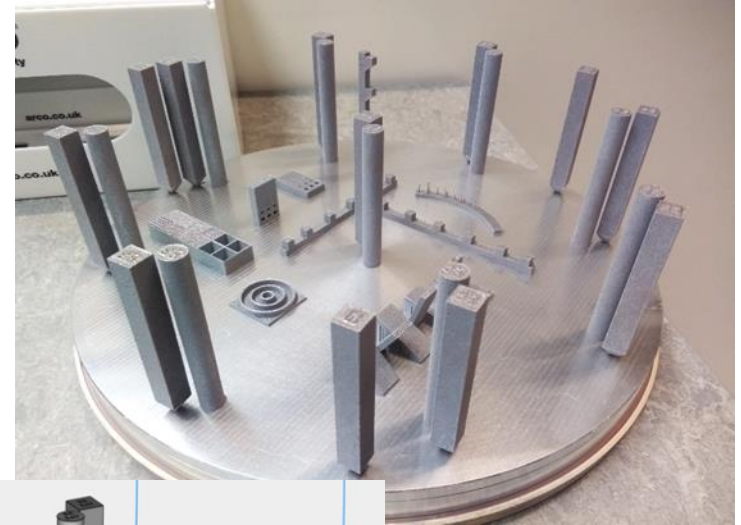
Documentation and record keeping requirements are to be determined based on business needs

# Not Just About Documentation and Data

You may need to retain samples:

Witness samples

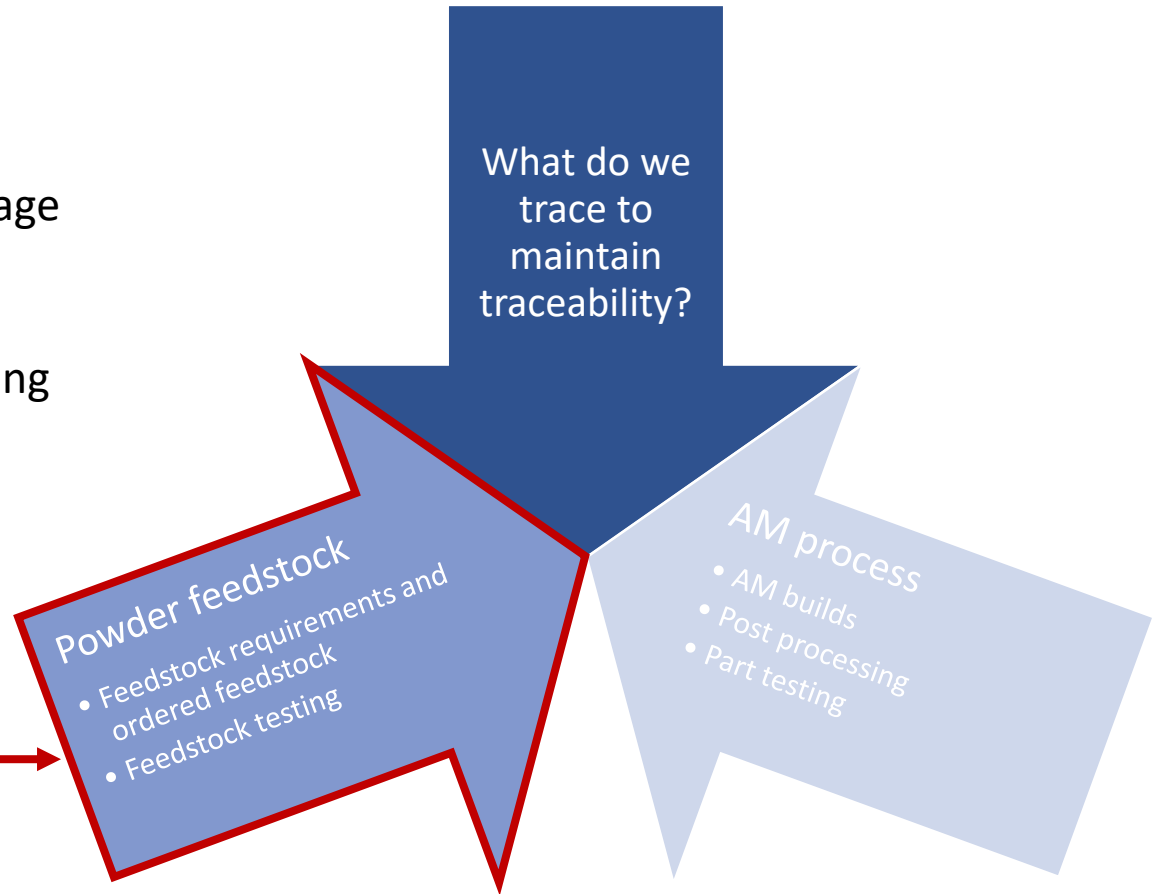
Powder samples



# Chain Traceability in Additive Manufacturing

- Feedstock procurement
- Feedstock receipt and storage
- Feedstock testing
- Production & post processing

We will focus on powder feedstock to show the depth of information



# Feedstock procurement

- Feedstock requirements need to be retained (a proposal, copies of emails, excel spreadsheet)

**Procurement e-form** and **purchase order** are evidence of the conformity of the ordered feedstock to specified requirements

## ***Information captured:***

- Supplier details
- Product description
- Material type
- Alloy name
- Alloy specification
- Quantity
- Nominal particle size
- Customer purchase order



# Feedstock receipt and storage

## Certificate of Conformity (CoC)

### Information captured:

- Supplier
- Customer Purchase Order
- Alloy name
- Supplier batch number
- Dispatch number
- Weight
- Nominal particle size
- Alloy specification
- Number of certificate of analysis

**Powder tracker** is a log of all powder batches in stock

### Information captured:

- MTC batch ID
- Supplier batch number
- Date received
- Manufacturer
- Initial weight and a number of containers
- Current weight and a number of containers
- Location
- Material type, alloy name, nominal particle size
- AM process, AM machine
- Feedstock status (active, retired, top-up, quarantined, exhausted, not in use, contaminated)



	Base Material
Al	Aluminium
Fe	Iron/Steel
Ni	Nickel
Ti	Titanium
CONF	CONFIDENTIAL
Other	Other

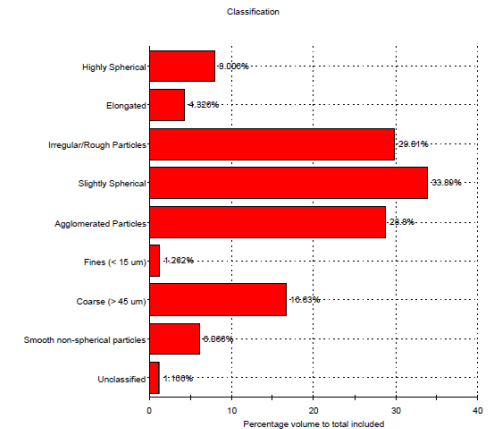
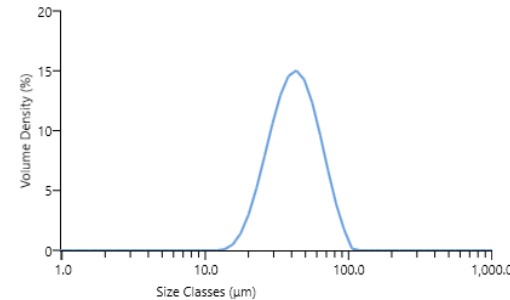
# Feedstock testing

## Sample testing log

- The log of all powder samples tested

### ***Information captured:***

- Materials Lab Sample ID
  - MTC batch ID/supplier batch number
  - Sample description (e.g. project name, project code, build ID)
  - Material
  - Alloy name
  - Weight
  - Date
  - Additional information
- All samples and material test data are labelled in a standardised way and can be identified using the Materials Lab Sample ID

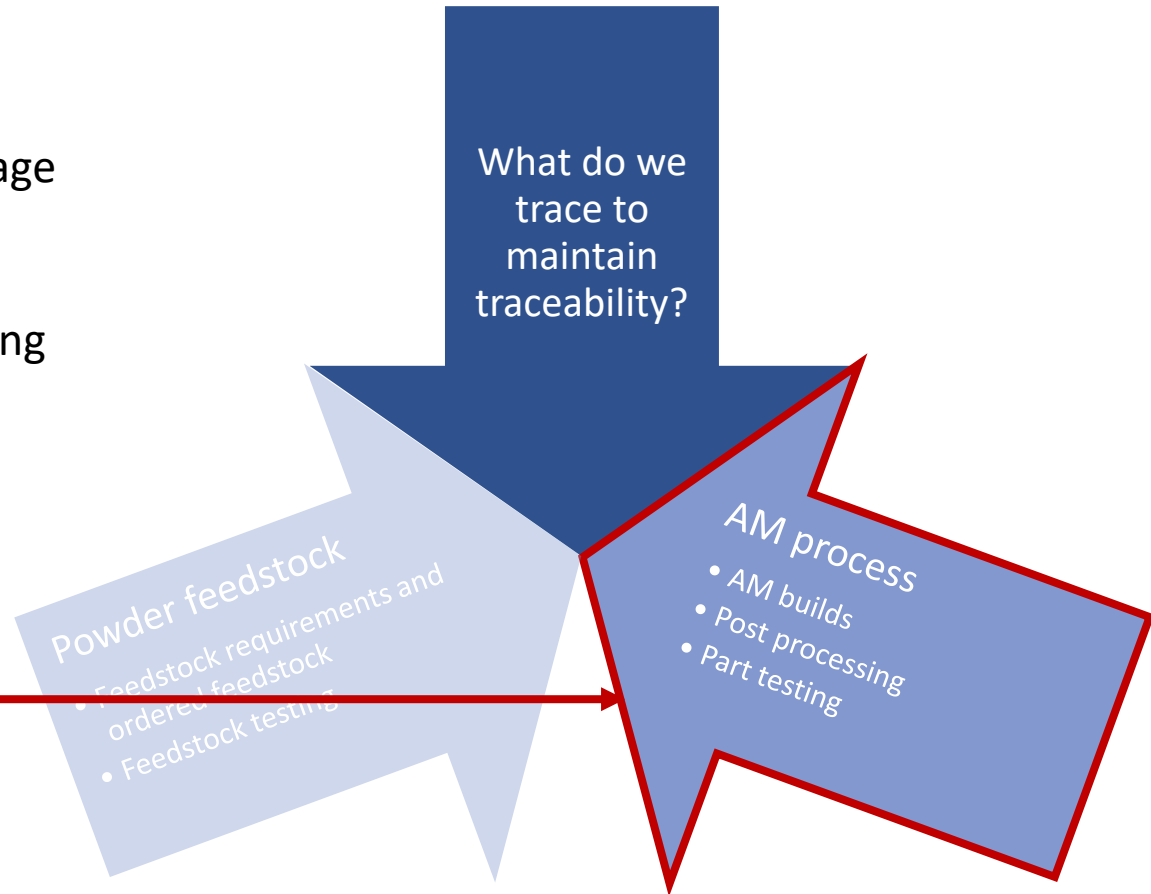




# Chain Traceability in Additive Manufacturing

- Feedstock procurement
- Feedstock receipt and storage
- Feedstock testing
- Production & post processing

We will focus on AM process to show the depth of information





# Production & Post processing: Data Register for Process Chain

	Matrix	Data Register							
Project	34930-01	34930-01							
Customer									
AM Machine	RenAM500Q								
Material	Ti6Al4V								
MTC Job Request Reference		20004		20024		20081		20203	
Folder No.	Zipper Folder	Build 1		Build 2		Build 3		Build 4	
	Data Category	Data Description	Data/Folder ID	Data Description	Data/Folder ID	Data Description	Data ID	Data Description	Data ID
1	Powder	CoC		CoC		CoC		CoC	
	MTC Powder Batch	MTC Powder Batch Validation	MTC0152 validation report	MTC Powder Batch Validation	MTC0152 validation report	MTC Powder Batch Validation	MTC0152 validation report	MTC Powder Batch Validation	MTC0152 validation report
2	CAD design	25mmx21mm Plate	1mm Plate_V1.0						
	Part Drawing	n/a	n/a						
3	AM Build Requirements	Build and process requirement definition		Build and process requirement definition		Build and process requirement definition		Build and process requirement definition	
4	AM Build Model	STL of all parts and support	14-MTC-AM500Q-STLs	STL of all parts and support	15-MTC-AM500Q-STLs	STL of all parts and support	16-MTC-AM500Q-STLs	STL of all parts and support	18-MTC-AM500Q-STLs
		Magics Project File	14-MTC-AM500Q	Magics Project File	15-MTC-AM500Q_UPDATED	Magics Project File	16-MTC-AM500Q	Magics Project File	18-MTC-AM500Q
5	E-stage parameters	E-stage Parameters		E-stage Parameters		E-stage Parameters		E-stage Parameters	
6	Melt Theme	AM500Q Ti 60 micron Default	AM500Q_Ti64_60micron_V1.0	AM500Q Ti 60 micron Default	AM500Q_Ti64_60micron_V1.0	AM500Q Ti 60 micron Default	AM500Q_Ti64_60micron_V1.0	AM500Q Ti 60 micron Default	AM500Q_Ti64_60micron_V1.0
7	QuantAM File	QuantAM File	14-MTC-AM500Q.amx	QuantAM File	15-MTC-AM500Q.amx	QuantAM File	16-MTC-AM500Q.amx	QuantAM File	18-MTC-AM500Q.amx
8	Machine File	MTT Machine File	14-MTC-AM500Q_S.mtt	MTT Machine File	15-MTC-AM500Q_Quad.mtt	MTT Machine File	16-MTC-AM500Q_2laser	MTT Machine File	18-MTC-AM500Q_2laser
9	Heat Treatment	Furnace Thermocouple Data from Cycle	20004_HT Cycle Data_14-MTC-AM500Q	Furnace Thermocouple Data from Cycle	20024&20081_HT Cycle Data_15&16-MTC-AM500Q	Furnace Thermocouple Data from Cycle	20024&20081_HT Cycle Data_15&16-MTC-AM500Q	Furnace Thermocouple Data from Cycle	20224-HT Cycle Data-18-MTC-AM500Q
10	Metallurgy Inspection	Density measurement on carrier specimens	MTC Build Quality Assurance_RenAM500Q	Density measurement on carrier specimens	MTC Build Quality Assurance_RenAM500Q	Density measurement on carrier specimens	MTC Build Quality Assurance_RenAM500Q	Density measurement on carrier specimens	MTC Build Quality Assurance_RenAM500Q
		Hardness Testing Control Plan and Results							
11	Metrology Inspection In-situ with Build Plate	n/a	n/a	GOM Report		GOM Report		GOM Report	
	Metrology Inspection of parts	GOM Report	Sean-Anthony Smith 34930-01 scan 1 Report	GOM Report		GOM Report		GOM Report	
		CMM Report	n/a	CMM Report		CMM Report	1/2/3/4_-08_07_27_08_2020	CMM Report	
12	Visual Inspection of build and part	Images of build and processing of parts	14-MTC-AM500Q-Build&Part Images	Images of build and processing of parts	15-MTC-AM500Q-Build&Part Images	Images of build and processing of parts	16-MTC-AM500Q-Build&Part Images	Images of build and processing of parts	18-MTC-AM500Q-Build&Part Images
13	Simulation	n/a	n/a	Magics Files and Simulation Images	Magics Files & Images	Magics Files and Simulation Images	Magics Files & Images	Magics Files and Simulation Images	Magics Files & Images

# Chain Traceability in Additive Manufacturing

AM build requirements are defined and retained in  
**AM Build Requirements Capture Sheet**

## Build Log

- Dedicated for each AM platform
- Contains documentation for all AM builds (build file, production pack, machine logs)

Each AM build has a unique **AM build ID** that allows the build identification



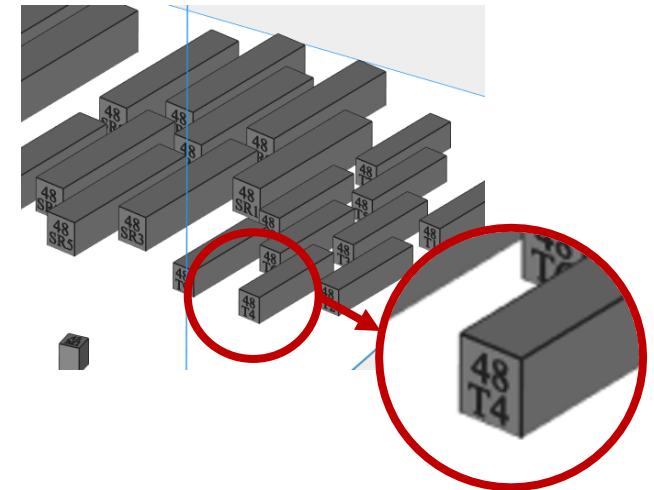
# Chain Traceability in Additive Manufacturing

## Production Pack

- Contains the **AM Route Card** and **Process Record Sheets** dedicated for each operation specified in the AM Route Card

### *Information captured in the AM Route Card:*

- Materials Lab Sample ID
- Issuer
- Powder batch
- Project
- Job number
- Build number
- Date issued and delivery date



## AM Route Cards and Process Record Sheets

- Allow to trace operations; process and machine conditions; Work Instructions and procedures that have been followed for each operation; post processing and part testing

**Build file** allows part identification for the build and tracing a part location on the build plate

# Traceability for AM: Layer History Opportunity vs Challenge

As components build up layer by layer in AM each layer process needs a specification and record to capture manufacturing history – **Layer validation in AM**

This forms the basis of key challenges in AM:

- How do I confidently **capture, store and then analyse thousands of layer data** sets to validate production run
- How do I **prove and then control consistency of each** layer and resulting component

However the layer information is advantageous:

- **Material evolution information** can be sought to **manipulate and control material evolution** in a single component
- **Anomalies and single point defects** once a given process window is found can be **identified on each layer** of a given component with correlation of layer information to part quality information
- The opportunity of layer **signal processing and machine learning** could lead to significant advancements in driving **efficient production yield and cost saving**

# Traceability for AM: In-Process Monitoring Available for AM

AM Process	Machine Manufacturer	'Module' name	Failure Mode Monitored	Parameter Altered	Equipment
Electron Beam Powder Bed Fusion	Arcam	LayerQam™	Porosity	N/A	Camera
Laser Powder Bed Fusion	B6 Sigma, Inc. (specialist)	PrintRite3D® INSPECT™	Unknown	N/A	Thermocouple and high speed camera
Laser Powder Bed Fusion	Concept Laser	QM melt pool	Melt pool monitoring	Laser Power	High-speed CMOS-camera
Laser Powder Bed Fusion	EOS	N/A	Unknown	N/A	Camera
Direct Energy Deposition	DEMCON	LCC 100	Melt pool monitoring	Laser Power	Camera
Direct Energy Deposition	DM3D Technology	DMD closed-loop feedback system	Melt pool monitoring and build height	Laser Power	Dual-colour pyrometer and three high-speed CCD cameras
Direct Energy Deposition	Laser Depth	LD-600	Depth measurement	Laser Power	Inline coherent imaging
Direct Energy Deposition	Promotec	PD 2000	Melt pool monitoring	N/A	CMOS-camera
Direct Energy Deposition	Promotec	PM 7000	Melt pool monitoring	N/A	1D photo detector
Direct Energy Deposition	Stratonic	ThermaViz system	Melt pool temperature	Laser Power	Two-wavelength imaging pyrometer

Source: KHUB-AM-0010-Correlation of IPM Data to XCT Inspection -v1.0

# Traceability for AM: In-Process Monitoring Available for AM

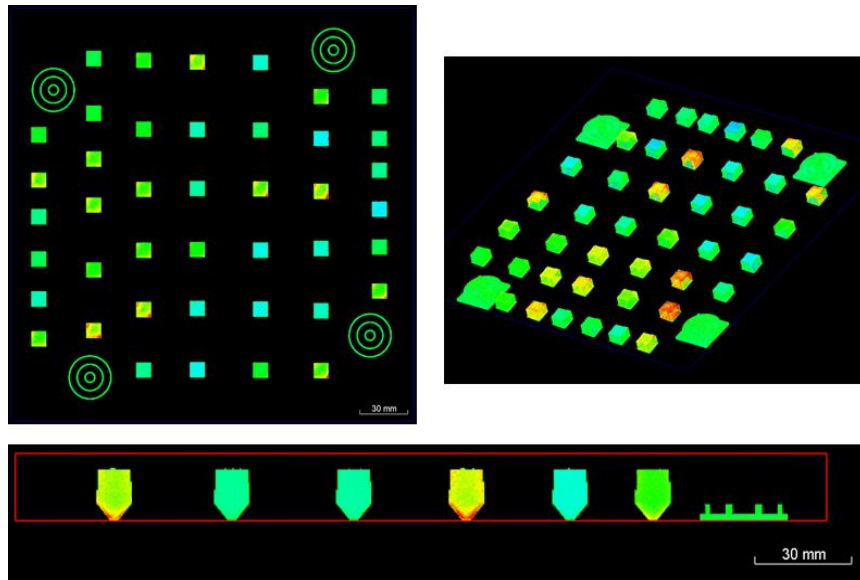


Figure. IPM data representation in the Renishaw InfiniAM Spectral software generated by MTC.

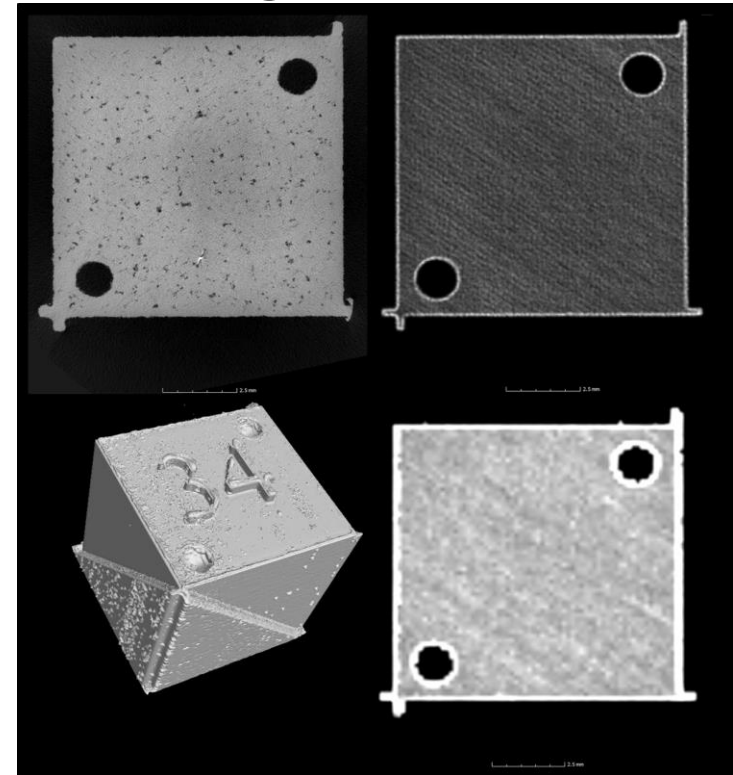


Figure. IPM data representation for single layer against XCT image for the same sample and layer

Source: KHUB-AM-0010-Correlation of IPM Data to XCT Inspection -v1.0

# Tools enhancing Traceability in AM

- Enabling data management of metal powders, parts, conditions across multiple locations, multiple machines and processes, providing audit trail and full traceability.

	3 <sup>rd</sup> party software	DIY software
Advantages	<ul style="list-style-type: none"> <li>Expert software developers</li> <li>Regular updates</li> <li>Customer support</li> <li>Ease of implementation</li> <li>Designed for this application</li> <li>Automatic data input</li> <li>Entire product lifecycle management</li> </ul>	<ul style="list-style-type: none"> <li>No additional licensing costs</li> <li>Completely customisable</li> <li>Ease of use</li> <li>Can implement in phases</li> </ul>
Limitations	<ul style="list-style-type: none"> <li>Licensing cost</li> <li>Less customisable</li> <li>Need to learn new software</li> <li>Need to align with production style</li> <li>Tied into production</li> <li>Links into other system software systems</li> </ul>	<ul style="list-style-type: none"> <li>Likely to be complex spreadsheets</li> <li>Time consuming to set up and maintain</li> <li>Software capability will be limited</li> <li>Links into other software systems</li> </ul>





Co-funded by the  
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*Questions ?  
& Thank you*

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