AM INTERACTION DAYS

David Hardacre, Lloyd's Register

Certification of AM products

AMable

SAM SECTOR SKILLS STRATEGY IN ADDITIVE MANUFACTURING

EU Industry Week 2021 #EUIndustryWeek

About LR

Lloyd's Register Foundation & Group

1. LR Foundation is a charity
2. Its mission is to enhance safety of life and property, and advance public education
3. It is based in the UK but gives grants globally
4. It is the sole shareholder of the Lloyd’s Register Group
5. Impact and excellence are the major grant-giving criteria
6. >$27M donated to LR Foundation to support science & engineering research and education

Why certify?

Why certify?

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ARE YOU— AM — READY?

Safety

- Consumers
- Operators
- Members of the public
- Assets
- Environment

Flixborough disaster – 1974
28 lives lost, 36 non-fatal injuries

Concorde – 2000
113 lives lost

Piper Alpha – 1988
167 lives lost

Bhopal disaster – 1984
>3787 lives lost, >500,000 non-fatal injuries

Why certify?

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ARE YOU— AM — READY?

Safety

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Benchmarking

Product assurance

- Industry & market acceptance (safety of product for intended application)
- Confirms legal requirements are met
- Provides assurance of quality and capability to manufacturers, clients and users

Why certify?

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ARE YOU— AM —READY?

Safety

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Self-certification

- Aerospace: CAA
- Medical: FDA
- Mining: Country specific (e.g. Indian Bureau of Mines)
- Automotive

Product assurance

- Industry & market acceptance (safety of product for intended application)
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3rd party certification

- Oil & gas
- Marine
- Energy
- Construction

Qualification & Certification

LR provides material and part **certification** but facility **qualification**

- To understand the difference, we first need to understand the difference between **verification** and **validation**
- Very simplistically:
  - **Verification**: are all the right things in there?
  - **Validation**: are all the things in there, right?

- For example, if assessing a spreadsheet, then:
  - verification would involve checking that all required formulas were entered correctly in order to calculate the required outputs (i.e. auditing)
  - validation would involve checking that the values were calculated correctly, usually by use of specific test cases (i.e. testing)

Why certify?

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ARE YOU— AM —READY?

So, in terms of additive manufacturing…

- A **qualified facility** is one that has been **verified** as having the necessary equipment, personnel, processes, etc. to produce the outputs that they have been qualified for
- **Certified materials & parts** are the outputs from a qualified facility that have been **validated** as satisfying the requirements of a specific regulation, code, standard or specification

"Qualification is possible without certification but certification requires qualification"

- Confusion sometimes arises since a **certificate** is issued for both certification and qualification - unfortunately, there is no such thing as a **qualificate**!

Project stages

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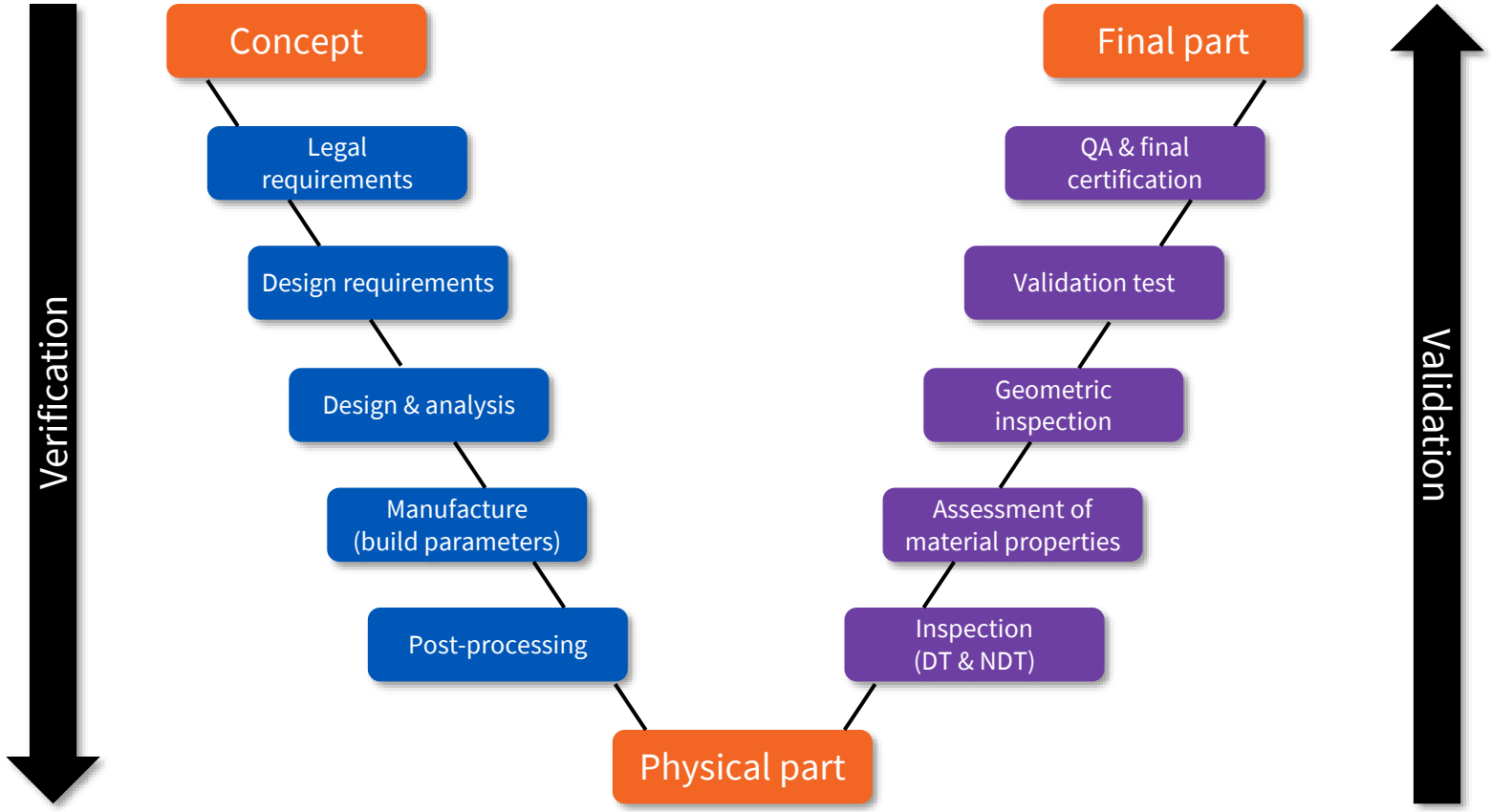

Functional stages for certification

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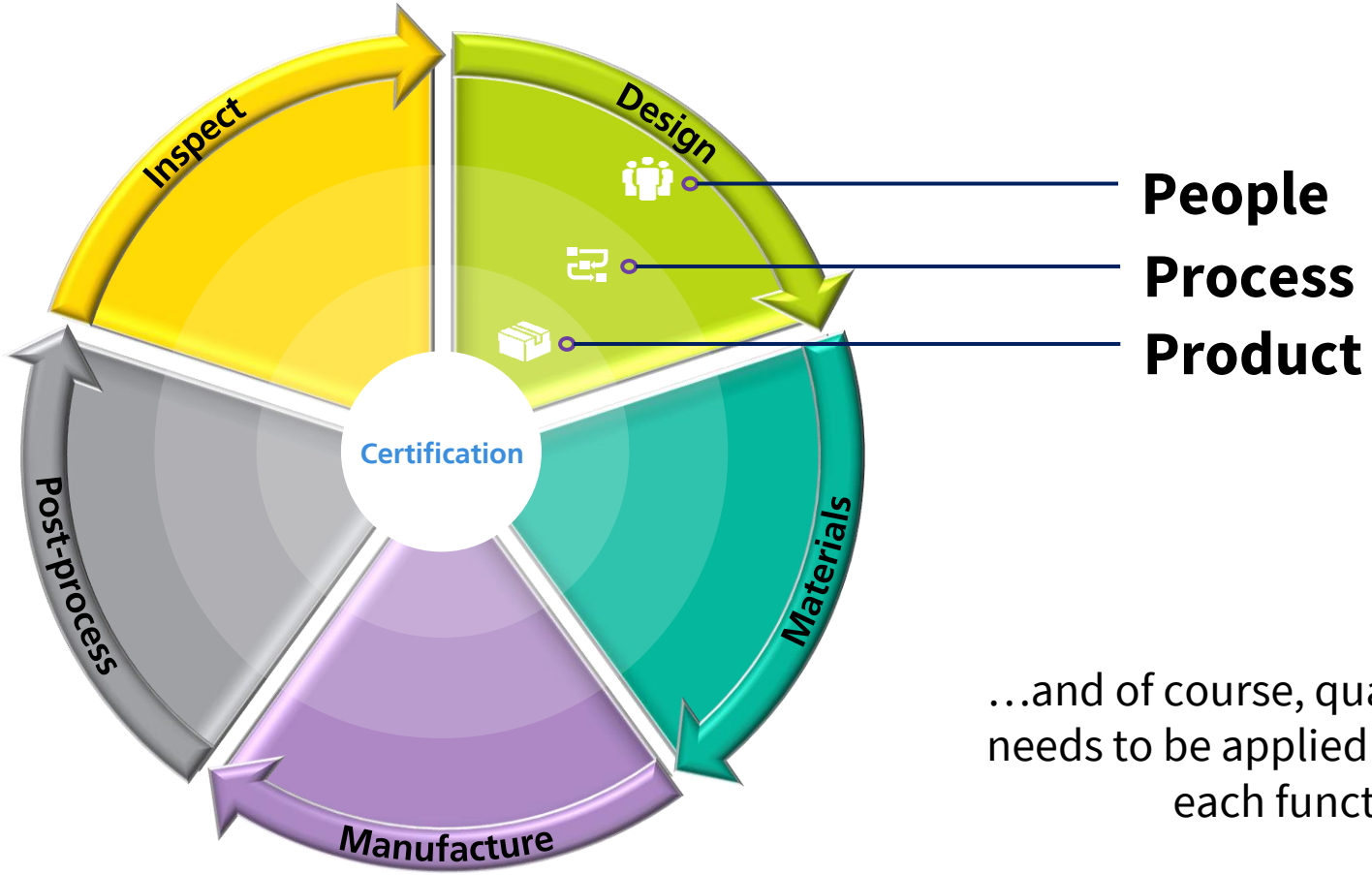
Within each area of activity, the tasks can be further sub-divided into:

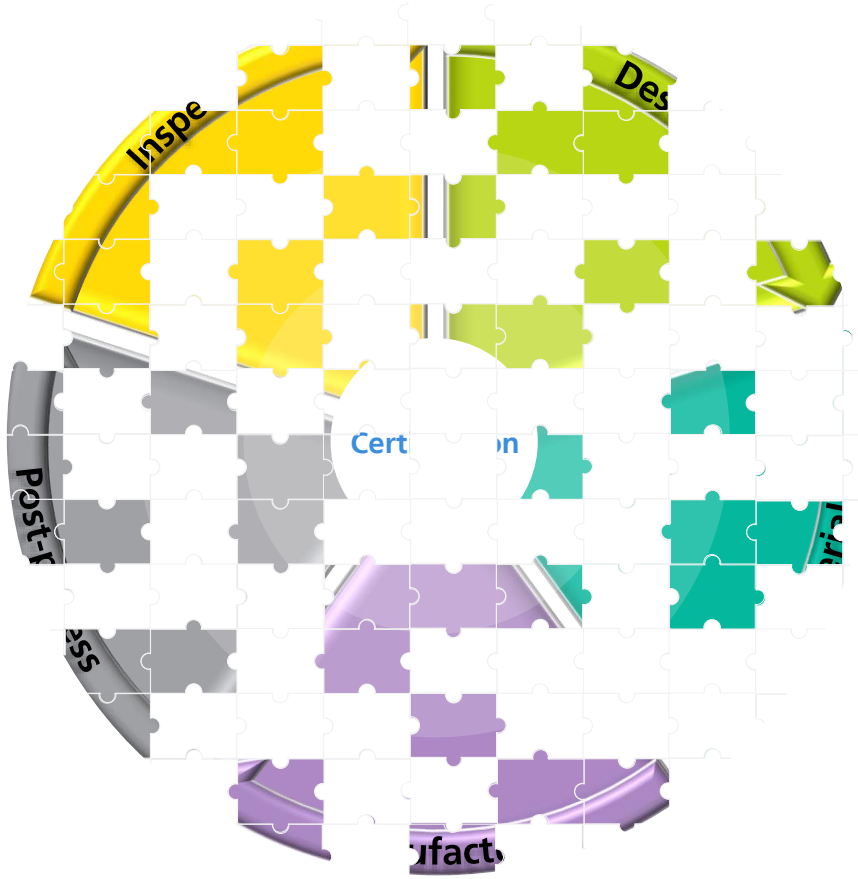


…and of course, quality control needs to be applied throughout each functional stage.

Functional stages for certification

Application specific standards

- Aspects of these can be used for AM, where relevant
- AM-specific information is not typically provided in these standards at the moment
- Questions arise, for example:
  - What material properties to use?
  - Is a design factor required?
  - Are existing fatigue curves applicable for AM?
  - Are current inspection techniques capable of detecting AM-specific flaws?
  - Are AM builds repeatable? What are the causes of variation?



Functional stages for certification

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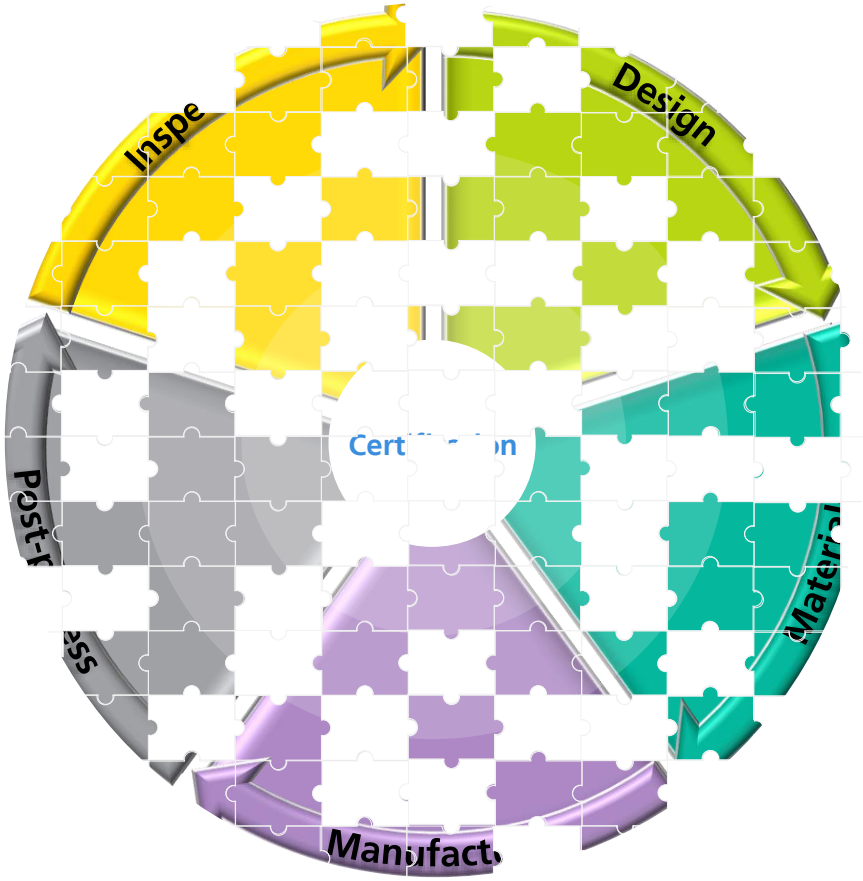

AM specific standards

- Fills the gaps within the industry standards for AM
- Not many AM-specific standards available yet

Functional stages for certification

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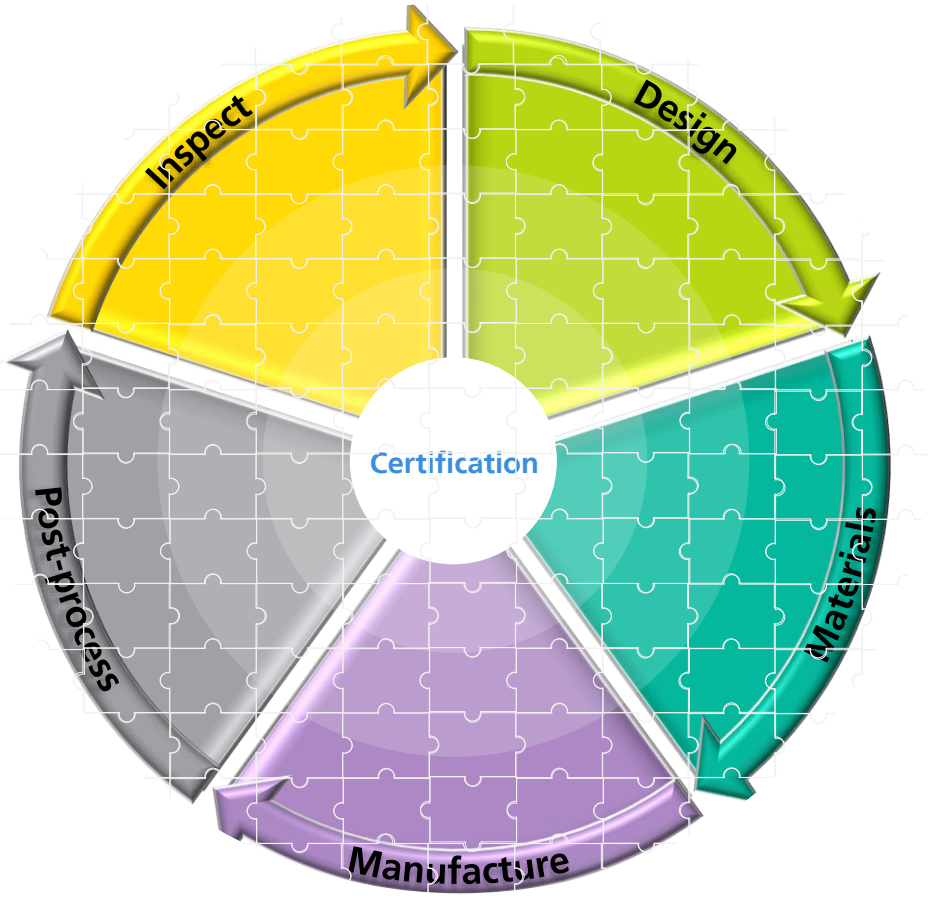

AM specific standards

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Technology Qualification

- Used where neither industry-specific nor AM-specific standards are available
- Guidance provided by Regulator or Inspection Authority

Application-specific standards

API 20S: AM metallic materials for use in the petroleum & natural gas industries

- The API 20S Standard is designed to play a crucial role in leveraging Additive Manufacturing (AM) to foster innovation in the oil and gas industry and encourage a safer, broader, and faster adoption of AM technologies in the mainstream oil and gas applications.

- Initial draft is complete and is currently progressing through the review & ballot stage:
  API Ballot: 5386-API 20S, 1st Edition

- Ballot closes 24th March 2021

Application-specific standards

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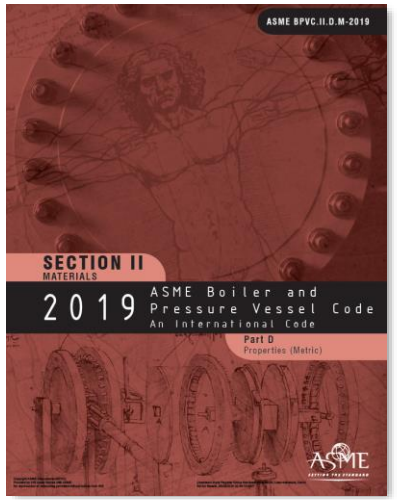
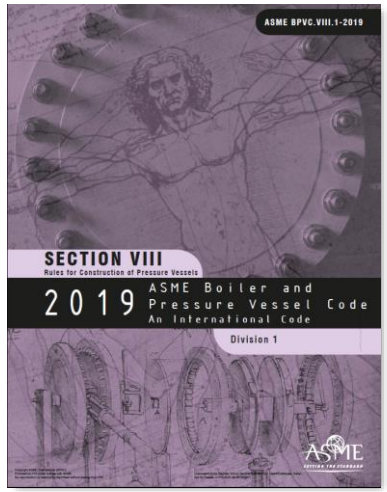
ARE YOU— AM — READY?

ASME BPTCS/BNCS Special Committee

- Charter: to develop a technical baseline to support development of a proposed BPTCS standard or guideline addressing the pressure integrity governing the construction of pressure retaining equipment by additive manufacturing processes. Construction, as used in this Charter, is limited to materials, design, fabrication, examination, inspection, and testing.
- This Committee has now produced the final draft of "ASME Criteria for Pressure Retaining Metallic Components Using Additive Manufacturing" which is currently being balloted (Ballot #21-179).
- Scope is limited to powder bed fusion (laser and electron beam energy sources) at the moment (DED-Arc to follow).
- Once approved, the criteria will be published as a Pressure Technology Book (PTB) and used as a reference document for proposals for AM Code Cases or incorporation of AM into construction codes.

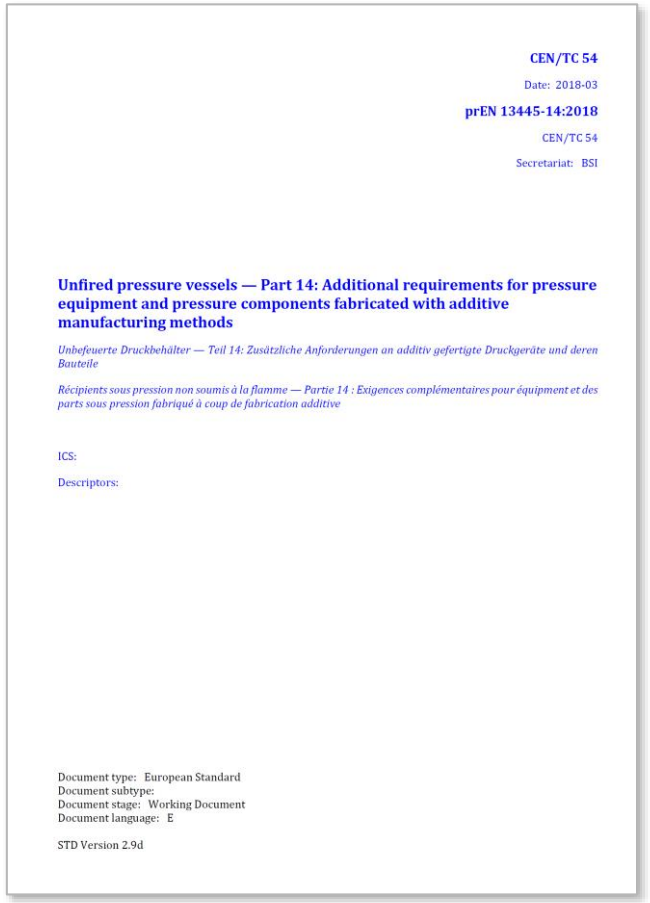




Application-specific standards

CEN/TC 54: Unfired pressure vessels

- **EN 13445 Part 14** has been drafted a new to incorporate requirements for pressure components by AM
- Includes sections on:
  - Materials (including nominal design stress rules)
  - Design & fabrication rules (including documentation & identification)
  - Inspection & testing (including Quality Factor for different levels of NDE)
  - Separate annexes for different AM processes (e.g. Annex A for powder bed fusion; Annex B for direct energy deposition with wire; etc.)
  - Each annex further sub-divides by specific material requirements (e.g. B.1 General requirements for DED-wire; B.2 DED-wire and steel; B.3 DED-wire and aluminium; etc.)



CEN/TC 54

Date: 2018-03

prEN 13445-14:2018

CEN/TC 54

Secretariat: BSI

Unfired pressure vessels — Part 14: Additional requirements for pressure equipment and pressure components fabricated with additive manufacturing methods

Unbefeuerte Druckbehälter — Teil 14: Zusätzliche Anforderungen an additiv gefertigte Druckgeräte und deren Bauteile

Récipients sous pression non soumis à la flamme — Partie 14 : Exigences complémentaires pour équipment et des parts sous pression fabriqué à coup de fabrication additive

ICS:

Descriptors:

Document type: European Standard
Document subtype:
Document stage: Working Document
Document language: E

STD Version 2.9d

AM-specific standards

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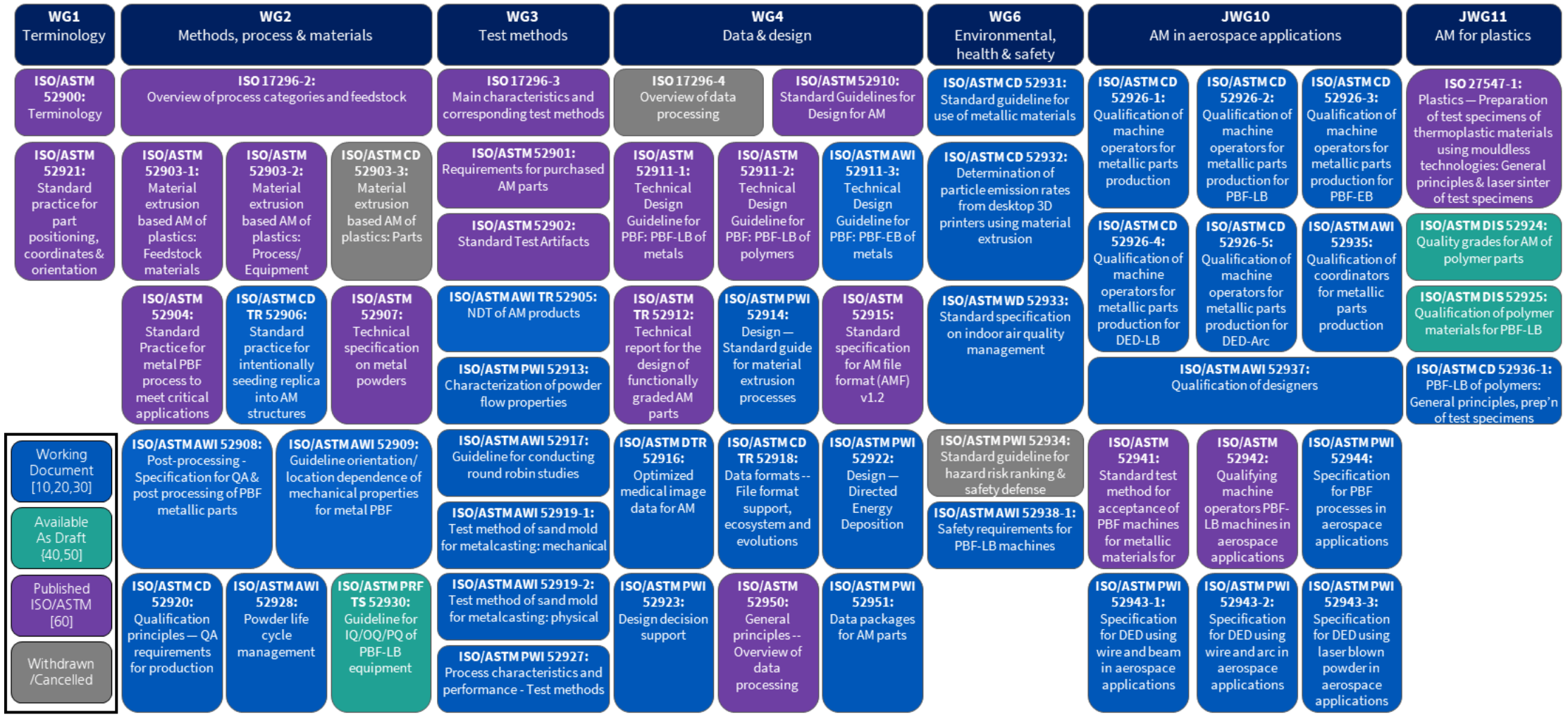

AM-specific standards

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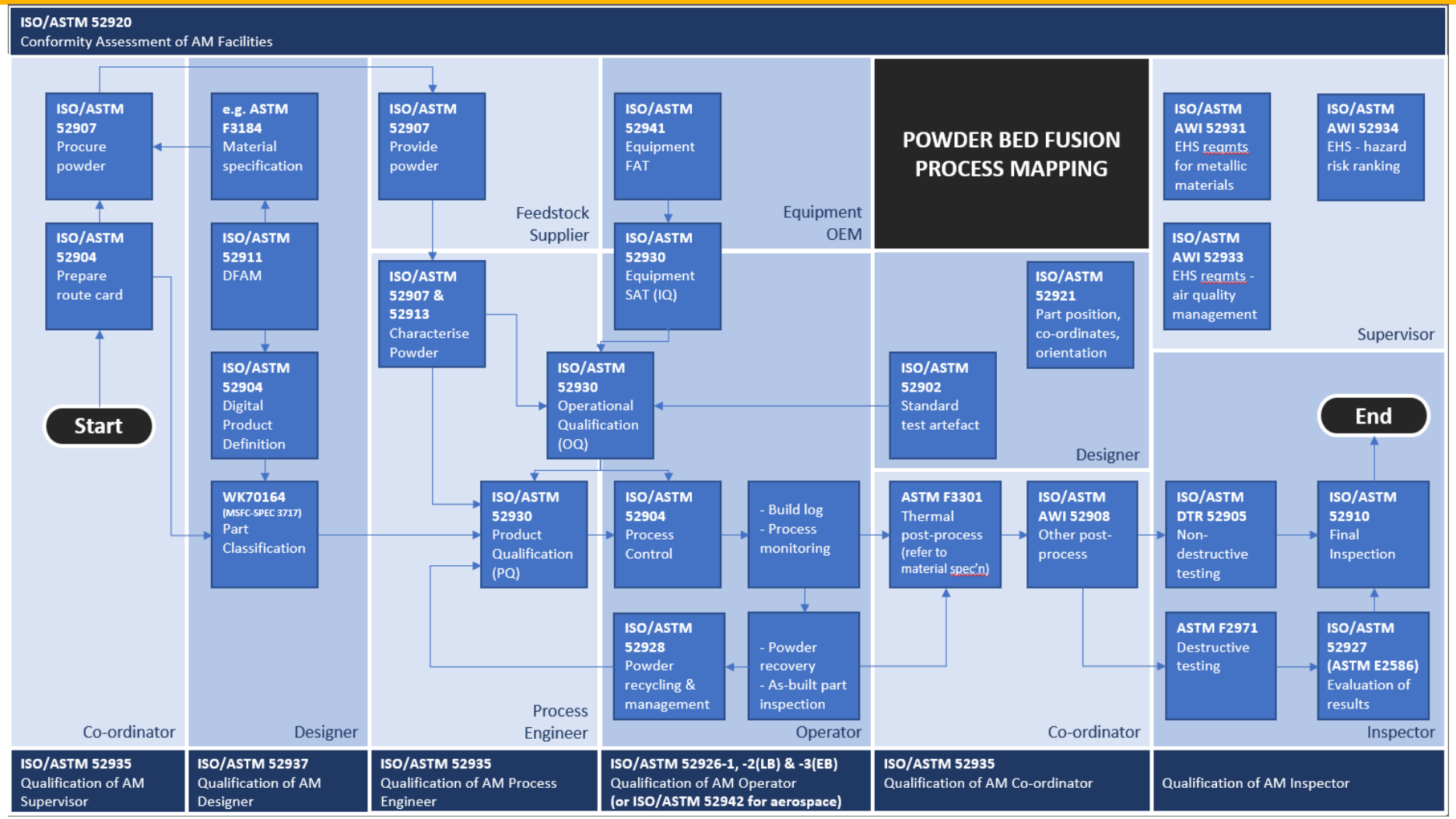

Certification hierarchy

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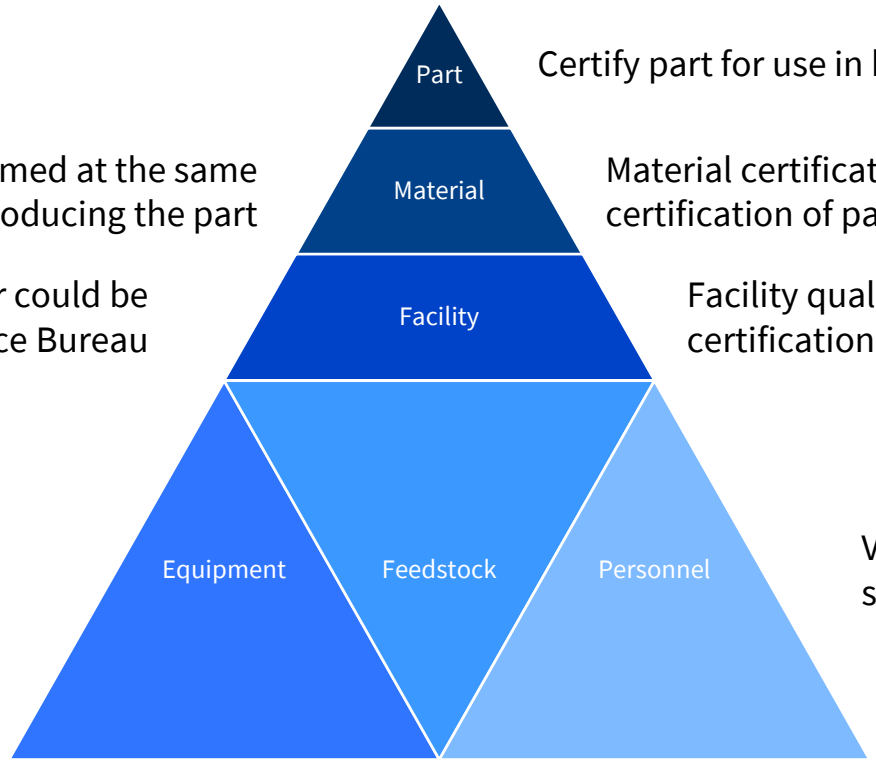

Certify part for use in known application

In AM, the material is formed at the same time as producing the part

Material certification is pre-requisite for certification of part

This may be an in-house AM facility or could be sub-contracted to AM Service Bureau

Facility qualification is pre-requisite for certification of part and material

Various under-pinning aspects for successful qualification of the facility

Certification hierarchy

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ARE YOU— AM — READY?

Why do we need personnel qualifications for AM?

IAMQS

Material specifications require it:

- EN 764-5 (metallic materials for pressure equipment)

e) The competent body shall evaluate by interviews or by the examination of documents:

1) that the manufacturing equipment and the equipment controlling the essential parameters are available. They shall be capable of permitting the consistent delivery of products in the required quality;

2) that competent personnel are available for operating and maintaining the equipment and supervising the manufacturing and inspection and testing activities;

Product standards require it:

- EN 13445-1 (unfired pressure vessels - general)

— the welder or welding operator shall be qualified, see 7.4 of EN 13445-4:2009.

- EN 13445-3 (design)

Due to the advanced methods applied, until sufficient in-house experience can be demonstrated, the involvement of an independent body, appropriately qualified in the field of DBA, is required in the assessment of the design (calculations) and the potential definition of particular NDT requirements.

- EN 13445-5 (inspection)

All inspections shall be carried out by qualified personnel.

Certification hierarchy

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Due to the advanced methods applied, until sufficient in-house experience can be demonstrated, the involvement of an independent body, appropriately qualified in the field of DBA, is required in the assessment of the design (calculations) and the potential definition of particular NDT requirements.

Additive Manufacturing cannot offer a loophole against existing regulations and requirements for conventionally-produced materials and parts

Certification documentation

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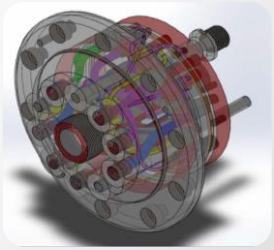
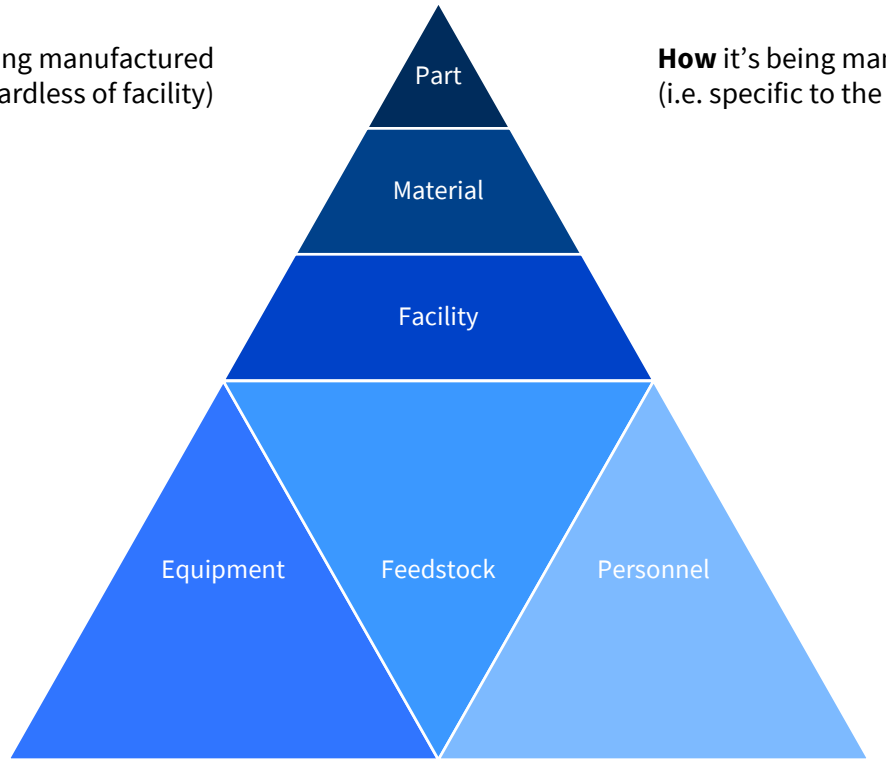
ARE YOU— AM —READY?

MANUFACTURING PLAN

What is being manufactured
(i.e. specific to the part, almost regardless of facility)

Manufacturing Plan





FACILITY PROCEDURES

How it's being manufactured
(i.e. specific to the facility, regardless of what is being made)

Facility Procedures

Certification documentation

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ARE YOU— AM — READY?

MANUFACTURING PLAN

FACILITY PROCEDURES

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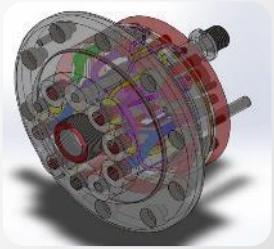

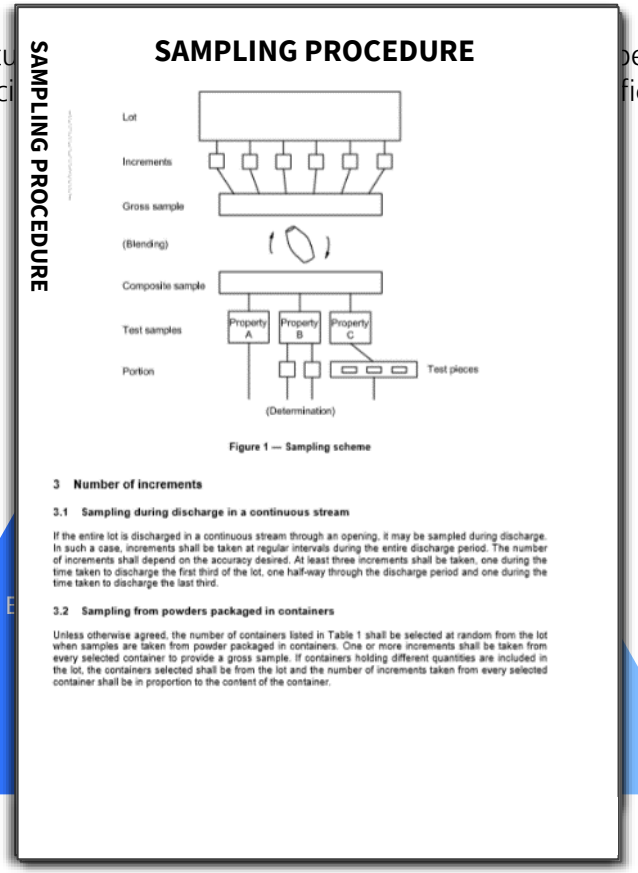

Facility Procedures

Certification documentation

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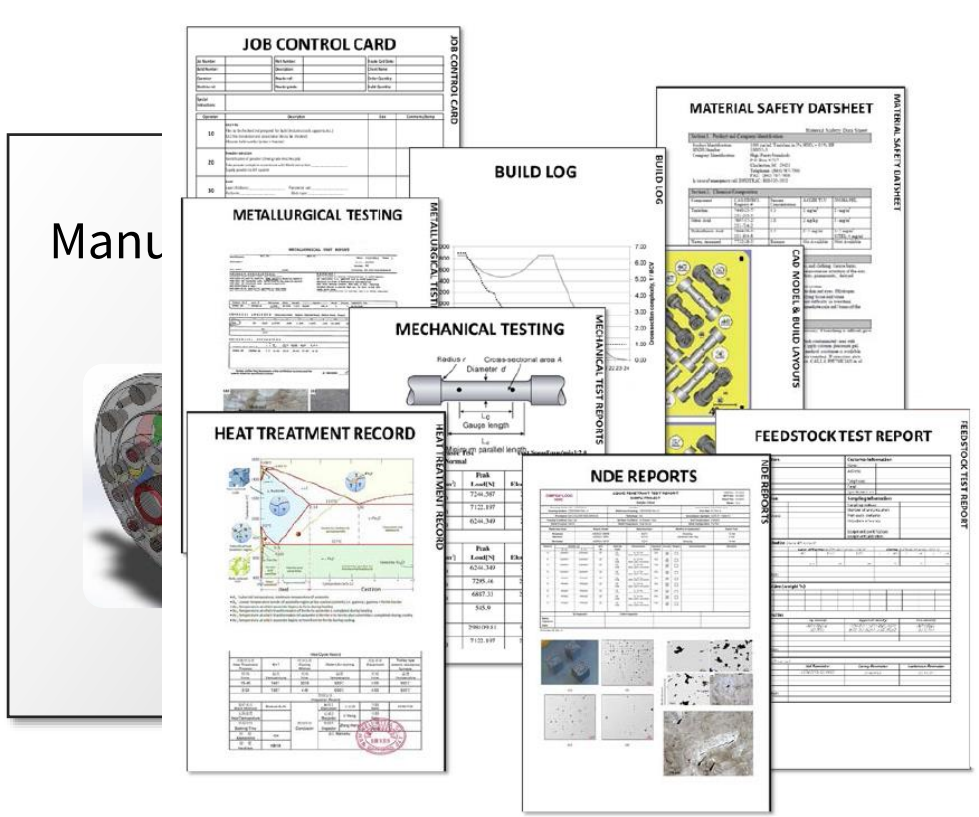
ARE YOU— AM — READY?

MANUFACTURING PLAN



FACILITY PROCEDURES

Certification project

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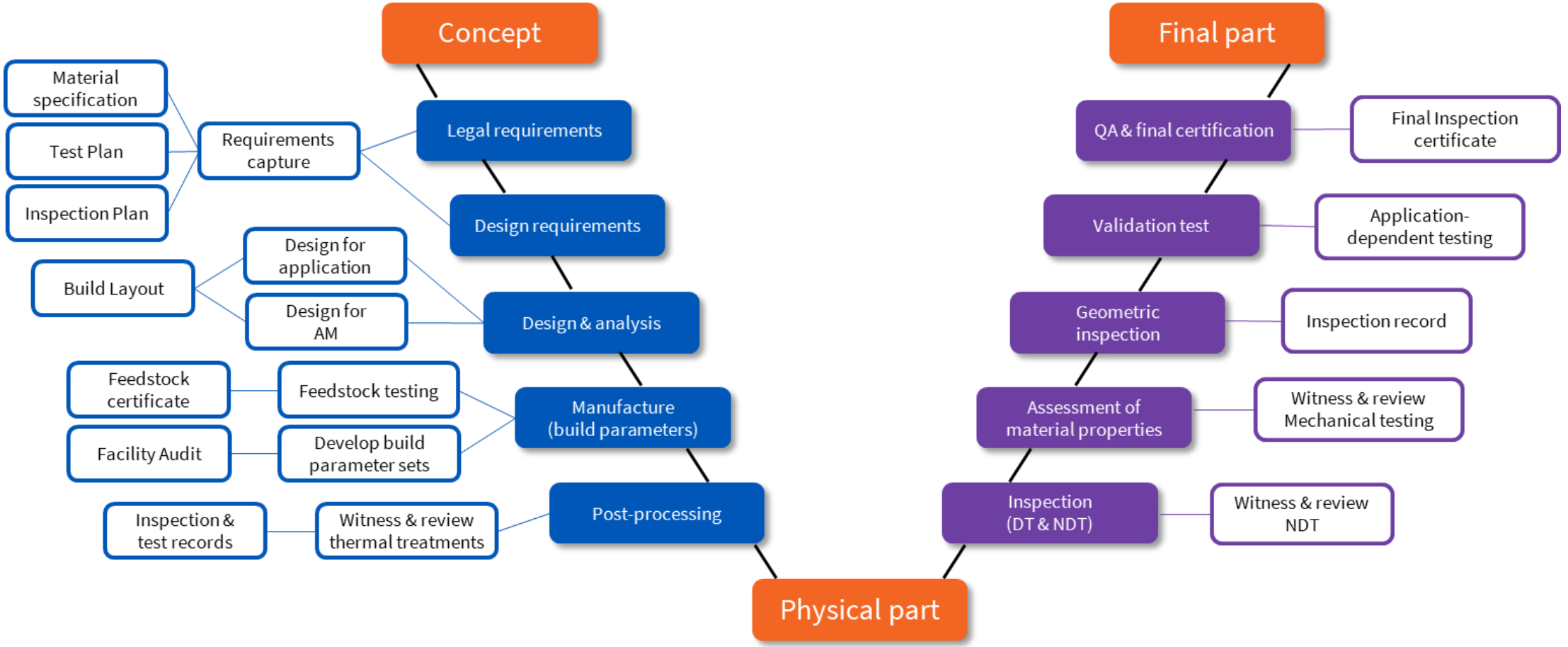

Certification project

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ARE YOU— AM —READY?

- Design Appraisal Document
  - Assessment of design against required regulatory, code and/or standards requirements
  - Independent calculations and assessment of build layout
  - Statement of Endorsement can be issued prior to progressing with build
- Material (powder, wire) certification
  - Witnessed material testing
  - Inspection report issued (to powder vendor or manufacturer, depending who performs the required testing)
- Additive manufacturing facility certification
  - Facility audit
  - Review of existing approvals, processes & procedures
  - Issue AM Quality Scheme Approval Certificate
- Post-process & inspection facility
  - Witnessed material testing
  - Material certification (formed material)
  - Inspection report issued
- Part certification
  - Limited in scope to the design, material, facility & manufacturing instructions used
  - Changes to any part of the process would require re-validation of the part certification

Certification project

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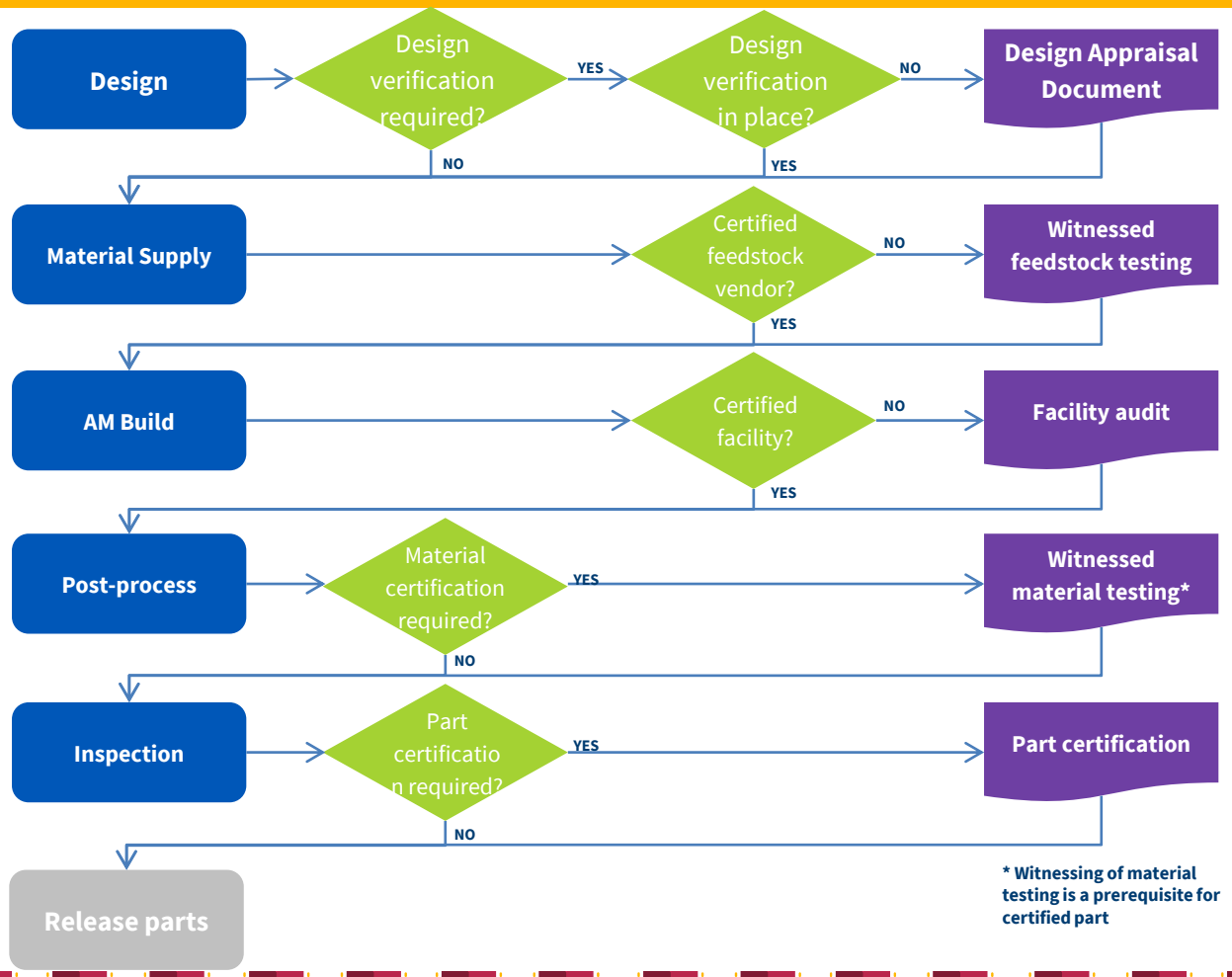
ARE YOU— AM —READY?

Modular approach

- Different organisations within the supply chain may perform activities within each functional stage
- Specific certification can be provided for each stage, which can then reduce the effort required for subsequent part design
- Using pre-qualified facilities can enable part manufacturers to reduce cost and lead times for part certification



Examples of Projects & Activities

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Joint Industry Projects

Rolls-Royce

ENGIE Laborelec

中广核 CGN 核能
Suzhou Nuclear Power Research Institute

Chevron

SULZER

PETROBRAS

Sellafield Ltd

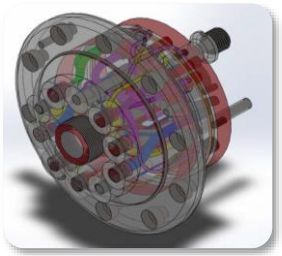
ConocoPhillips

中国航发 AECC
Aero Engine Corporation of China

BIAM
Beijing Institute of Aeronautical Materials

AVIC MANUFACTURING TECHNOLOGY INSTITUTE

AM Part Certification



AM Facility Qualification

Shell

AML3D

3D METAL FORGE

TWI

wipro

ENGIE

EOS

EOS Singapore Pte Ltd

TWI

Consultancy & Training

CLLAIM

Keppel

NANYANG TECHNOLOGICAL UNIVERSITY

Shell

Schlumberger

SINGAPORE POLYTECHNIC SP

UNIVERSIDADE FEDERAL DO RIO DE JANEIRO UFRJ

FLOWSERVE

Knowledge Sharing

EWF

ASME SETTING THE STANDARD

ISO

ASTM

cen

Thank you!

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David Hardacre | david.hardacre@lr.org

Find out more at: www.lr.org/additive-manufacturing

AMable

SAM SECTOR SKILLS STRATEGY IN ADDITIVE MANUFACTURING

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