The NUCOBAM Project – Incoporation of Additive Manufacturing into Nuclear Codes & Standards

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NUclear COmponents Based on Additive Manufacturing

NUCOBAM

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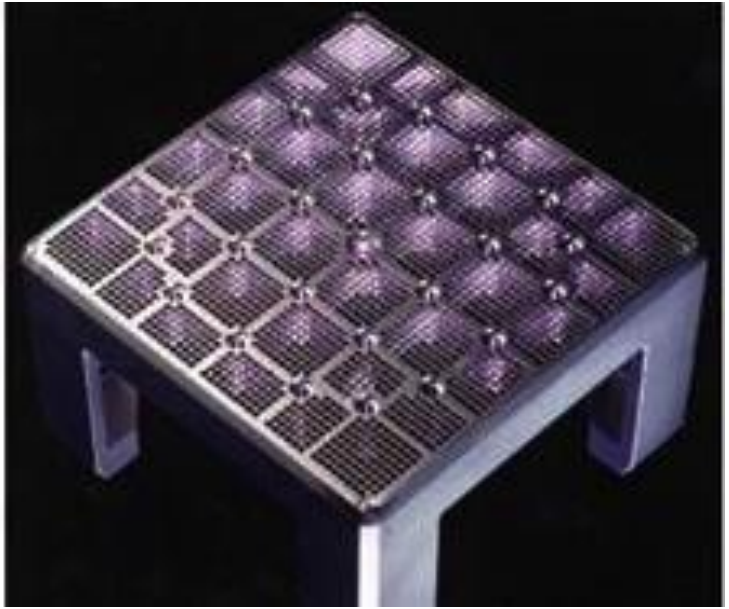
Background & Motivation

Additive Manufacturing (AM, 3D printing) in particular interesting for components with complex geometries.



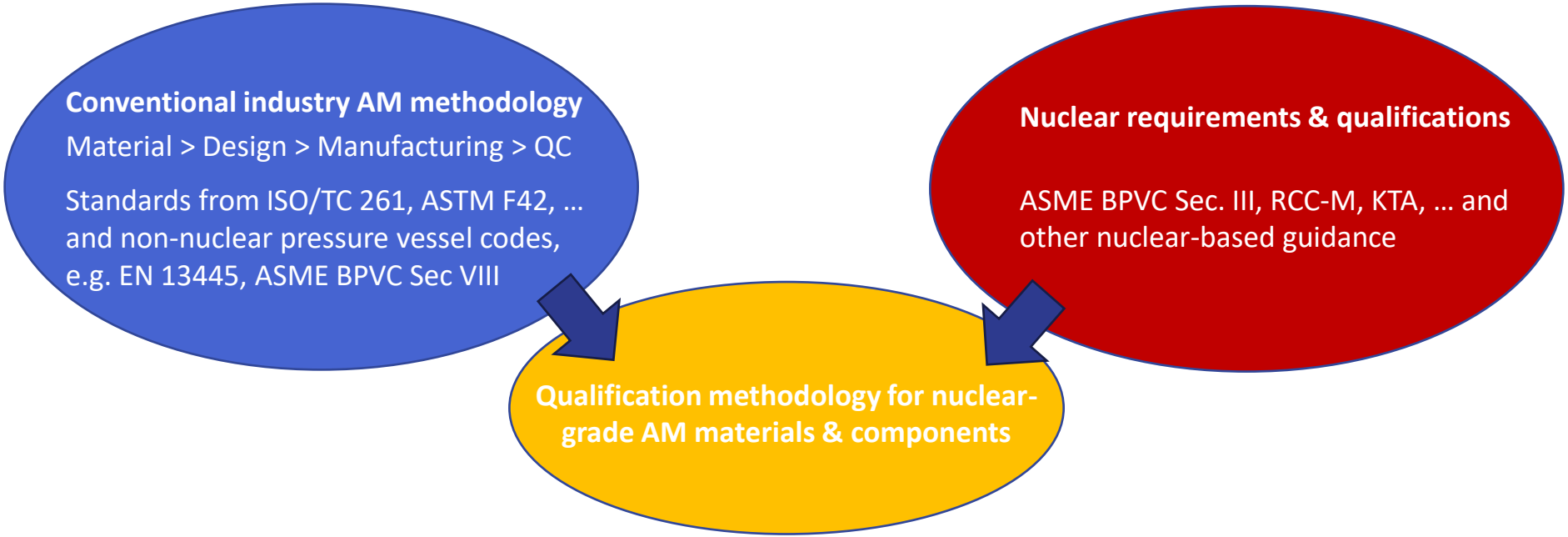
Fuel debris filter (© Framatome SAS)

AM also interesting to re-produce obsolete components (reverse engineering)

Housing of obsolete safety valve (© Tractebel-ENGIE)

Overall Project Goal

Safety-classified SSCs need to be designed, manufactured & QC according to stringent nuclear codes & standards (NC&S). This also applies to AM components.

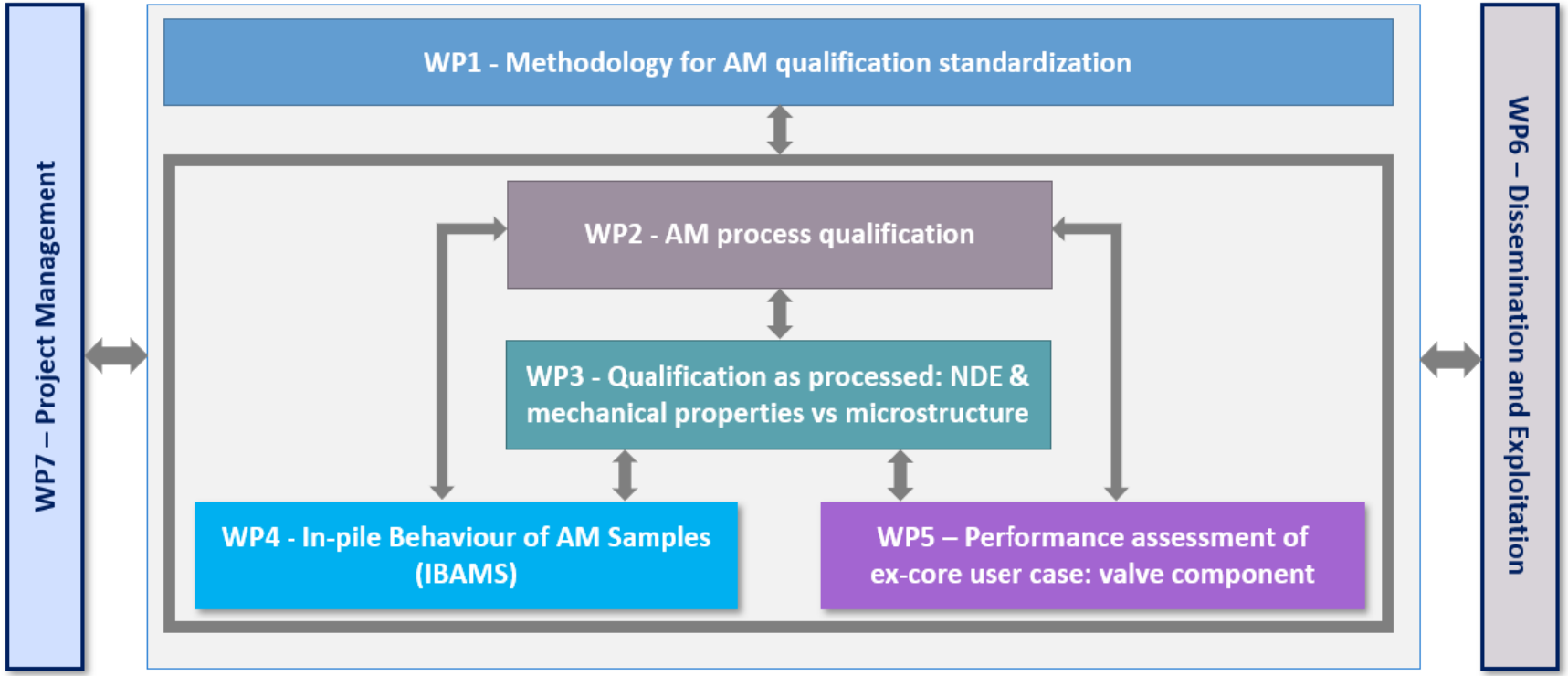


Overall project goal: Development of a methodology for qualifying materials & components produced via AM that comply with NC&S.

Project Facts

- **Title**: Nuclear Components Based on Additive Manufacturing (NUCOBAM)
- **Duration**: 48 months (start: 10/2020)
- **Budget**: ca. 4 Mio € (EC contribution: 3 Mio €)
- **Consortium (13 organisations)**: CEA, EDF, ENGIE-Lab, Tractebel-ENGIE, Naval Group, Framatome (F), CIEMAT, Univ. Sheffield (Nuclear AMRC), VTT, SCK-CEN, EC-JRC, Ramen Valves, IRSN
- 7 Work packages (5 technical + 1 dissemination and E&T + 1 proj. management)

Project Structure



Project Strategy

Draft Methodology (WP1) (Complete)

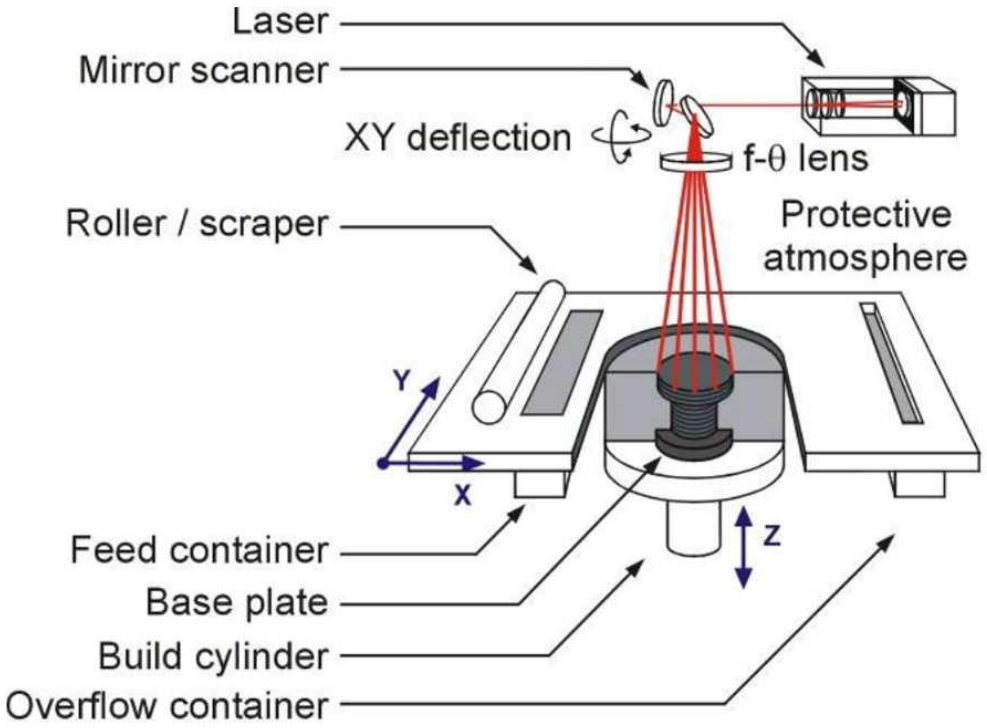
- AM process qualification & test coupon manufacturing (WP2)
- Characterisation of AM material (NDE) & mechanical test programme (WP3)
- Irradiation of AM specimen & PIE (WP4)
- Performance assessment of AM components (WP5)

Final Methodology ready for submission to NC&S committees (WP1) (At end of project)

WPs 3, 4 & 5 are performed in parallel.

Technical Scope: L-PBF

Applied AM process: **Laser-Powder Bed Fusion (L-PBF)**



Selectively fusing regions of a powder bed, layer by layer, with one or several lasers (selective laser melting (SLM)).

Material: **Austenitic stainless steel 316L**, as it is widely used in LWRs (reactor internals, primary pumps, valves, …)

WP2 AM Process Qualification

Aims:

1. Establish a qualified L-PBF process ensuring & demonstrating process stability, repeatability and reproducibility.
2. Produce test coupons for specimens for project test programme (WPs 3 + 4) and debris filter & valve housing for WP5.

L-PBF by 4 partner organisations (VTT, ENGIE-Lab, CEA, NAMRC) each using its own machine.

SLM equipment ENGIE-Lab ©

SLM equipment NAMRC ©

- QC measures during and after L-PBF (melt pool monitoring, small punch test)
- Application of 4 different post-heat treatments (including HIP) on test coupons, giving in total 16 different material variations

WP3 Test Programme and WP4 In-Pile Behaviour

- Characterisation of AM material via NDE (tomography, UT, X-ray, VT, checking for material inhomogeneities)
- Mechanical test programme on as-received AM material and thermally-aged AM material: tensile tests, hardness, Charpy impact, fracture toughness, fatigue, inter-granular corrosion, SCC testing (U-bend, SSRT), creep
- In WP4 irradiation of specimens (KLSTs, tensile & micrography specimens) of AM materials by SCK-CEN in BR-2 reactor, in Mol + PIE of irradiated specimens

WP5 Performance Assessment of AM Component

Valve test programme:

- Leak tightness (high & low pressure)
- Pressure resistance (hydrostatic test & burst test)
- Operability test (manoeuvrability & cyclic tests)

Component inspection (post-test):

- NDE to search for possible defects
- Destructive tests from same AM build platform to assess material microstructure and mechanical properties (tensile, impact toughness, hardness and density)
- Destructive tests from samples retrieved from the burst test of valve body

Draft Methodology

Overall approach: Provide requirements for all aspects for producing a safety-classified component via AM, thereby entirely making reference to existing ISO/EN and ASTM standards and NC&S (were collected beforehand).

Content (Sections, 10 in total):

1. General (Scope, quality & personnel qualification, traceability of specimens and documentation)
2. Terminology (essentially referring to standard AM terminology and powder metallurgy according to ISO/ASTM 52900, ISO/ASTM 52921, ASTM F2924, ASTM B243 + defining new terms (only if needed))
3. Documentation (equipment specifications, powder acceptance specifications, component manufacturing plan & reports, …)

Draft Methodology (2)

4. Powder Procurement

- Documentation & traceability (i.e. powder acceptance specification, statements of conformity, material certificates)
- Sampling (for powder characteristics analyses)
- Powder characteristics (i.e. particle size distribution, chemical composition, densities, morphology, flowability)
- Contamination
- Packaging, handling & storage
- Re-use of powder

Draft Methodology (3)

5. Qualification of the AM Process

- Preliminary AM procedure specifications (essential & non-essential variables for L-PBF, job control plan, job sheet, CAD file, job configuration file, parameter set file, laser scan trajectory file, machine file)
- Process stability (dimensions & number of samples, stability assessment tests, …)
- Process repeatability
- AM process qualification platform & tests
- Product validation platform
- Procedure qualification records

Draft Methodology (4)

6. Manufacturing of Component & Test Specimens

- Equipment specifications
- AM procedure specifications
- Component manufacturing plan (QC)
- Quality monitoring (manufacturing control system: witness samples, in-situ control, printer log files, examination of final qualified part (ref. to Section 10))

7. Heat Treatment

- Environment (Atmosphere) and procedure (e.g. temperature, soaking time, cooling) for 4 different conditions: Stress relief, 2 different solution annealing, hot isostatic pressing

Draft Methodology (5)

8. **Inspections & Tests**
    - Chemical analyses
    - Microstructure
    - Mechanical properties (tensile, hardness, impact toughness, density)
9. **Finishing of AM component** (Cleaning, pickling & passivation, removal of support material (machining, EDM), grinding, polishing)
10. **Examination (NDE of finished component)**

Draft methodology is available and is refined throughout the project.
Final methodology towards project end (mid 2024).

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NUCOBAM Partners

cea

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

EDF

ENGIE Laborelec

framatome

IRSN INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

Joint Research Centre JRC

NAVAL GROUP

sck cen

TRACTEBEL ENGIE

The University Of Sheffield.

VTT

Ramén Valves

Get in touch for more information:

Visit the project website: **www.nucobam.eu**

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