ADDITIVE MANUFACTURING AND ENVIRONMENT, HEALTH AND SAFETY ISSUES

Swissphotonics Workshop | Catherine L'ALLAIN – CEA Grenoble

PNS PLATE-FORME NANO SÉCURITÉ

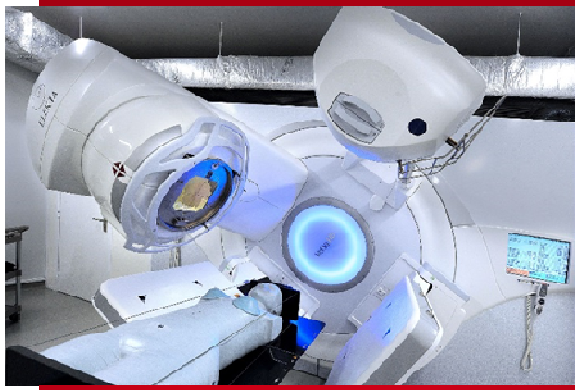
AGENDA

- **The NanoSafety Platform (PNS) – CEA Grenoble**
- **PNS and Additive Manufacturing**
- **Additive Manufacturing**
  - Technology, material and process
- **EHS issues**
  - Occupational risks
  - Particle exposure during metal AM
- **Conclusion**

THE NANOSAFETY PLATFORM (PNS)

CEA – TECHNOLOGICAL RESEARCH FOR INDUSTRY

- 3 CEA Tech'labs

LETI	LITEN	LIST
		
Micro-and nanotechnologies and their integration into systems	***New energy technologies and nanomaterials***	***Smart digital systems***
Foundation: ***1967***	*Foundation:* ***2005***	*Foundation:* ***2003***
Implantation: ***Grenoble***	*Implantation:* ***Grenoble / Chambéry***	*Implantation:* ***Paris Sud***
Workers: ***1600 people***	*Workers:* ***1100 people***	*Workers:* ***700 people***
Budget: ***€240 million***	*Budget:* ***€170 million***	*Budget:* ***€90 million***

Solar ines

PLATE-FORME NANO SÉCURITÉ

CEA – THE NANOSAFETY PLATFORM

KEY FIGURES

*A complete team of around **150** people*

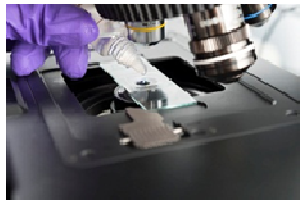
***€25 million** in investments*

***2,000** sq.m of lab space dedicated to R&D*

***400** workstations assessed*

The broadest range of nanosafety services in Europe

R&D



Medical and biological expertise

Detection
Measurement
Characterization
Monitoring

Training courses

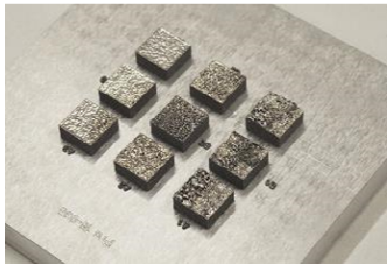
Incident and emergency response

PLATE-FORME NANO SÉCURITÉ

PNS AND ADDITIVE MANUFACTURING

CEA – LITEN AND ADDITIVE MANUFACTURING

- **Study of AM technologies for new energy applications**
- **Broad spectrum of activities:**
  - Powder characterization
  - Raw material formulation
  - AM process development
  - EHS expertise



Al 6061 by SLM
(3D System – CEA Tech)

Launch at CEA Grenoble of an EHS support program for AM, in the line of its experience of "nano-risk" management

Ensure the lowest possible exposure to powder for CEA workers

Transfer to CEA industrial partners safe technologies

Help the sector with other national stakeholders for a responsible development of AM regarding EHS issues

A COMPLETE OFFER TO SUPPORT THE ADDITIVE MANUFACTURING SECTOR

- Assistance with the design and development of industrial lines through an EHS approach
- Assessment of industrial processes
- Workstation measurement and monitoring
- Release and aging studies of manufactured products
- Training

ADDITIVE MANUFACTURING

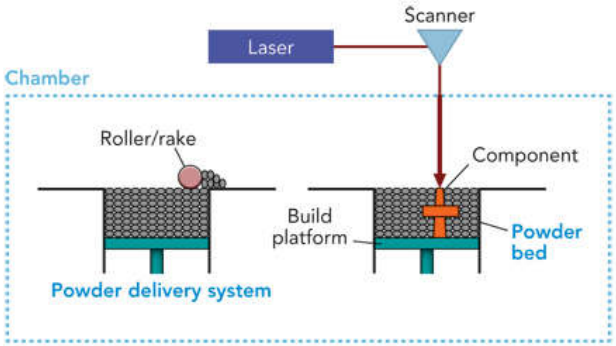
ADDITIVE MANUFACTURING

- **Definition**
  - “Process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies, such as traditional machining” *(ASTM standard F2792-10)*

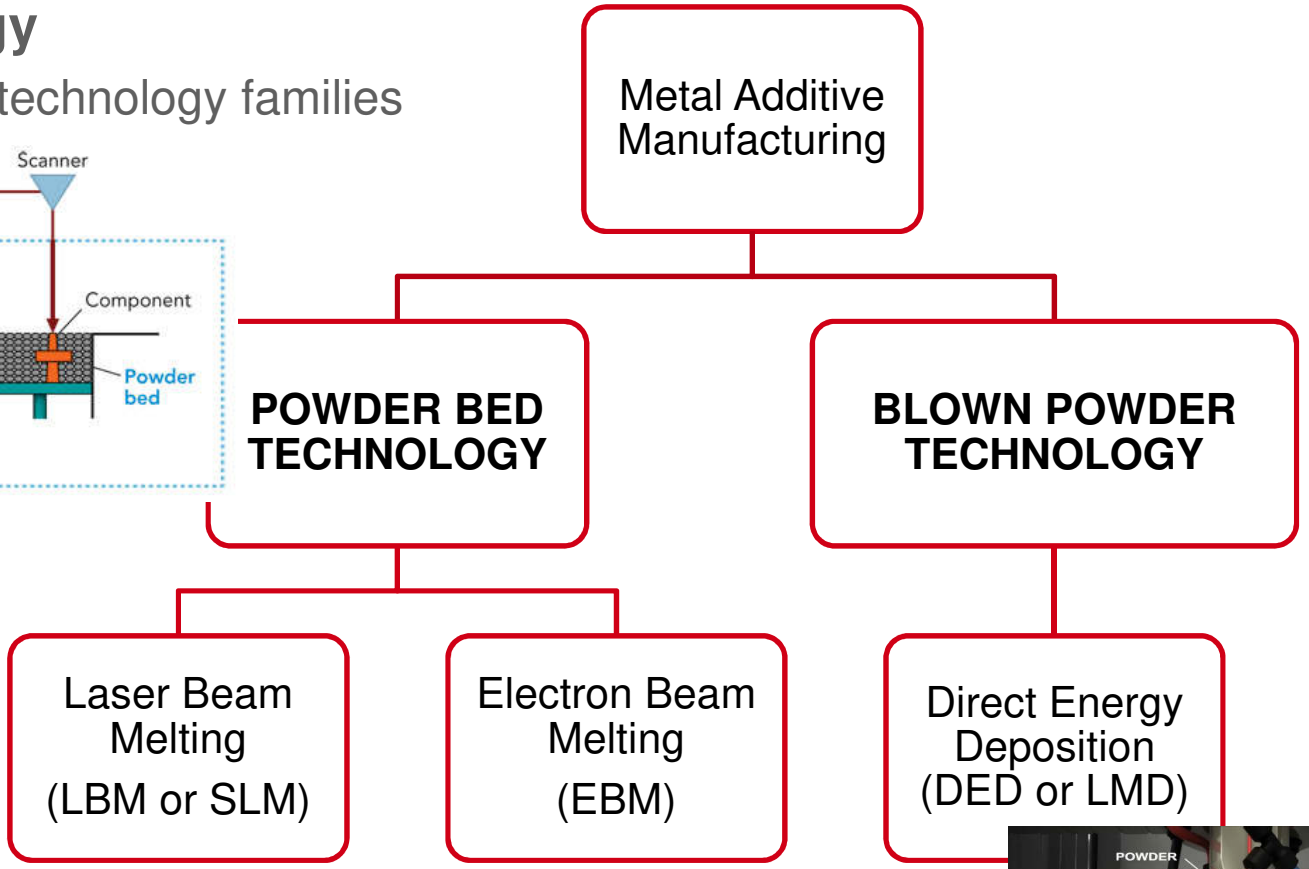
- **Material**
  - Plastic
    - Polymers or thermoplastics
      - ABS, PVA
  - Metal
    - Different alloys
      - Stainless steel
      - Nickel base
      - Cobalt Base
      - Titanium alloys
      - Aluminum alloys

METAL ADDITIVE MANUFACTURING

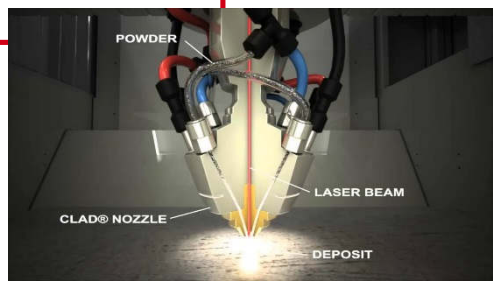
- **Technology**
  - 2 main technology families



Industrial lasers

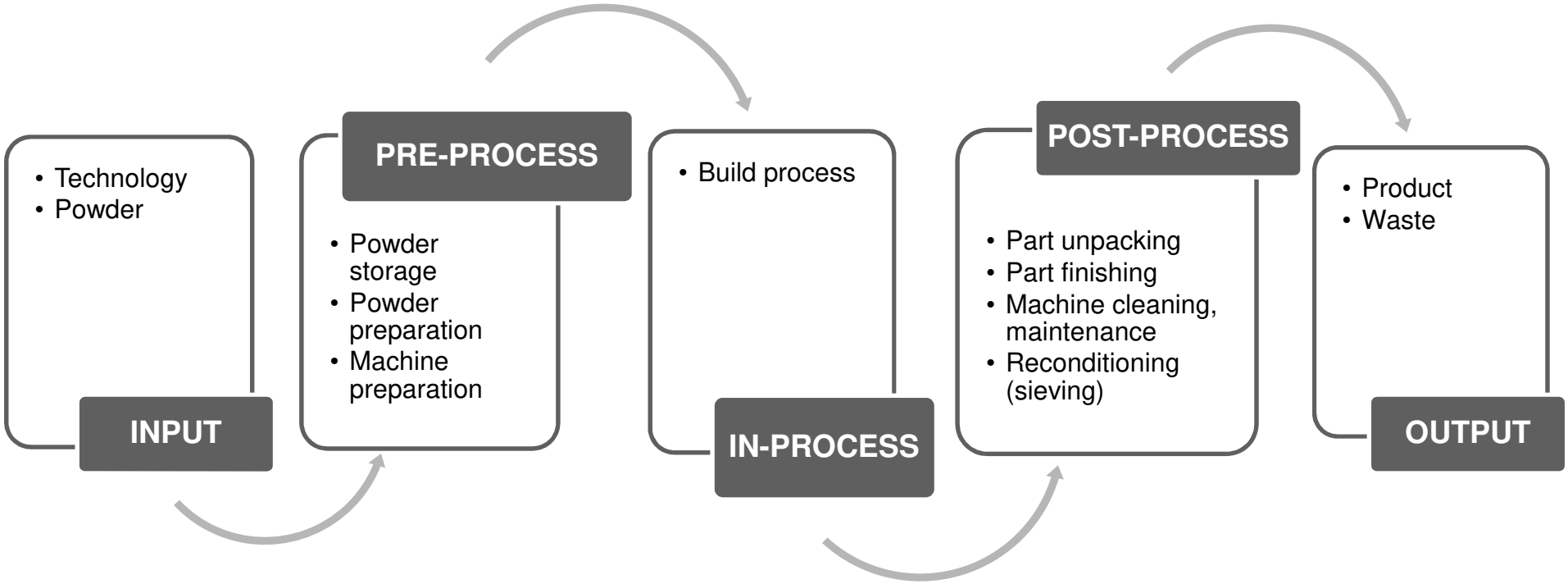


BeAM



METAL ADDITIVE MANUFACTURING

- **Process**



From Philippot, C. & al. Potential workers exposure measurement in metal additive manufacturing and how to manage it. Euro PM2018 Congress, Bilbao

EHS ISSUES

OCCUPATIONAL RISKS

- **Known and regulated risks**
  - Related to materials, equipment and operations performed
    - Exposure to metal dust
    - Fire / EXplosive ATmosphere (ATEX)
    - Laser
    - Handling / Working postures

- **Emerging risks**
  - Linked to the interaction of the laser with the powder and which depend on the technology and the material
    - Exposure to particulate aerosols, including a nanometric fraction
    - Potentially greater reactivity of “recycled" powders

EXPOSURE TO METAL DUST

- **Main route = inhalation**
- **Metal powders**
  - Main chemical components: Fe, Ni, Cr, Co, Al, Ti
  - Average particle size around 40 to 60 µm
- **Material Safety Data Sheet (MSDS)**
  - Example: 316L powder
    - Section 2: Hazards identification
    - Section 7: Handling and storage

SECTION 7: HANDLING AND STORAGE

7.1 Precautions for Safe Handling

Handling	Use personal protective equipment, see Section 8. Avoid generation of dust clouds/accumulation of dust in work area. Ensure good dust ventilation during handling. Formation of sparks and static electricity must be prevented. Earth all equipment. Provide grounding and bonding where necessary to prevent accumulation of static charges during metal dust handling and transfer operations . Avoid prolonged or repeated contact.

7.2 Conditions for Safe Storage, Including Any Incompatibilities

Storage Precautions	Keep locked up and out of reach of children. Avoid contact with incompatible materials, static, moisture, and flames. Keep away from heat, sparks and open flame. Avoid contact with oxidising agents. Store in tightly closed original container in a cool, dry and well-ventilated place.
Storage Class	Unspecified storage.

7.3 Specific End Use(s)

Specific End Use(s) Usage Description	The identified uses for this product are detailed in Section 1. Use only according to directions.

SECTION 2: HAZARDS IDENTIFICATION

2.1 Classifcation of the Substance or Mixture

Classification (EC 1272/2008)	
Physical and Chemical Hazards	Not classified
Human Health	Skin. Sens 1 - H317, Carc. 2 - H351, STOT RE 1 - H372
Environment	Not classified

2.2 Label Elements

Contains	nickel
Label in Accordance With (EC) No. 1272/2008	
Signal Word	Danger
Hazard Statements	H317 May cause an allergic skin reaction H351 Suspected of causing cancer if inhaled. H372 Causes damage to organs respiratory tract and lungs through prolonged or repeated exposure by inhalation
Precautionary Statements	Prevention P201 Obtain special instructions before use. P260 Do not breathe dust/fume/ gas/mist/vapours/spray. P280 Wear protective gloves/ protective clothing/eye protection/face protection. Response P370 + P378 In case of fire: Use class D (Dry Powder) extinguisher or sand for extinction. P302 + P352 IF ON SKIN: Wash with plenty of soap and water. P308 + P313 IF exposed or concerned: Get medical advice/ attention. Storage P405 Store locked up.
EUH Statements	EUH208 Contains nickel. May produce an allergic reaction

2.3 Other Hazards

Dust clouds may be explosive.
Powder or dusts in contact with water can generate flammable/explosive hydrogen gas.
Dust can irritate the eyes. High dust levels may irritate the respiratory system.

EXPOSURE TO METAL DUST

- **Material Safety Data Sheet (MSDS)**
  - Example: 316L powder
    - Section 8: Exposure controls/Personal protection

8.2 Exposure Controls

Protective Equipment

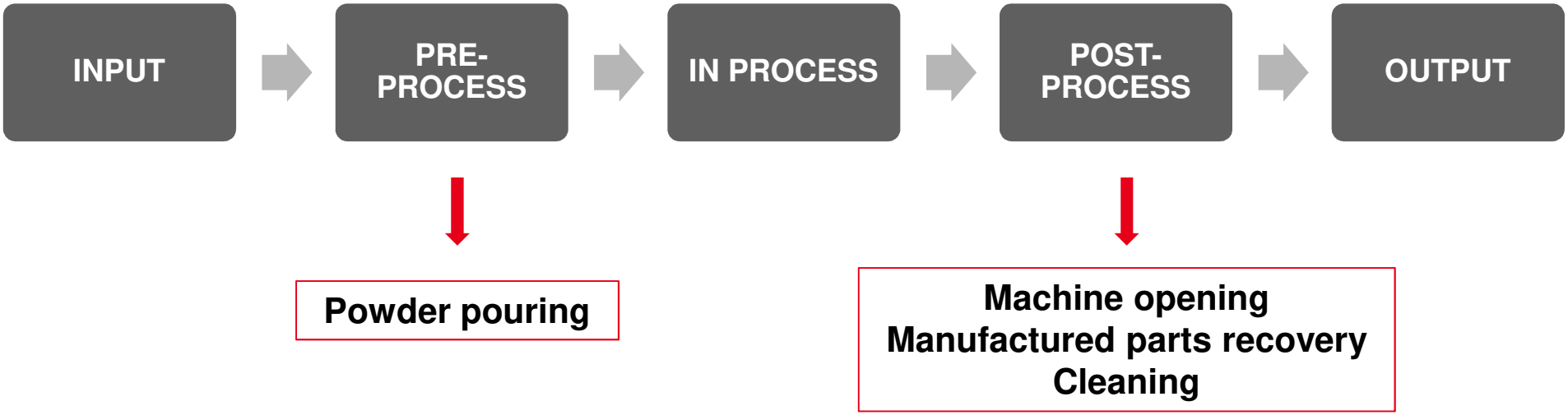
Engineering Measures	Provide adequate ventilation, including appropriate local extraction, to ensure that the defined occupational exposure limit is not exceeded. Use with adequate explosion-proof ventilation designed to handle metal particulates.
Respiratory Equipment	In case of prolonged or frequent exposure to particulates, wear particle filter mask (P3). Where risk assessment shows air-purifying respirators are appropriate a full face respirator conforming to EN 143 should be used, and suitable respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Change filters frequently Use respiratory protection as specified by qualified professional if concentrations exceed the limits listed in Section 8. Recommended: FFP3 (ref. standard 141/EN 143) type half mask. Use respiratory protection as specified by an industrial hygienist or other qualified professional if concentrations exceed the limits listed in Section 8.
Hand Protection	Use suitable protective gloves if there is a risk of skin contact. Suggested material: Nitrile rubber. Minimum layer thickness: 0.11 mm. Break through time: 480 min. Consult manufacturer for specific advice. Selection of the glove material depends on consideration of the penetration times, rates of diffusion and degradation, and concentration specific to the workplace. Where hand contact with the product may occur the use of gloves approved to relevant standards (e.g. Europe: EN374) is recommended. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Change gloves regularly.
Eye Protection	Wear safety goggles or face shield to prevent any possibility of eye contact. Use equipment for eye protection tested and approved under appropriate government standards such as EN 166(EU).
Other Protection	Wear appropriate clothing to prevent any possibility of skin contact. Suggested PPE: Fire resistant cotton or equivalent full-length overalls with electrically conductive safety shoes or grounding straps. Caution is required to avoid contact with unprotected electrical devices when wearing conductive safety shoes or grounding straps. Protective clothing should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling this product.
Hygiene Measures	Observe normal hygiene standards. Keep container tightly closed. Do not eat, drink, or smoke while using this product. Immediately take off any contaminated clothing and launder before re-use. Wash hands and / or face before breaks and at the end of the shift. After work, wash the skin and apply skin cream.
Process Conditions	Ensure that eye flushing systems and safety showers are located close by in the work place.

	German OEL mg/m³	French OEL mg/m³
Dust		
- Respirable	10	10
- Alveolar	1,25	5
Ni	0,006	1
Cr	2	2
Co	0,005	0,1
Welding fumes		5

EXPOSURE TO PARTICULATE AEROSOLS

- **Identification, characterization and assessment of potential exposure to airborne particles, during different working phases**
  - Real-time measurements and samples on site
  - Data analysis and physico-chemical characterization of on-site samples

- **Certain working phases more emissive than other**



EXPOSURE TO PARTICULATE AEROSOLS

- **Factors influencing emission and exposure**
  - Powder pouring
    - « Fresh » powders ←→ « Reused » powders
    - Closed door process ←→ Open door process
  - Machine opening and parts recovery
    - Technology
      - Powder bed or blown powder, laser power, etc.
    - Delay between end of production and equipment opening
    - Possibility of a pre-cleaning closed door
    - Working protocol for cleaning of printed parts
      - Mechanical operations

EXPOSURE TO PARTICULATE AEROSOLS

- **Factors influencing emission and exposure**
  - Cleaning
    - Closed door operation with an integrated vacuum cleaner
    - Easy access to different areas of the chamber, including with a glove-box system
    - Working protocol to recover powder surplus
    - Integrated sieving system

EOSINT, M 280
with confort powder modul

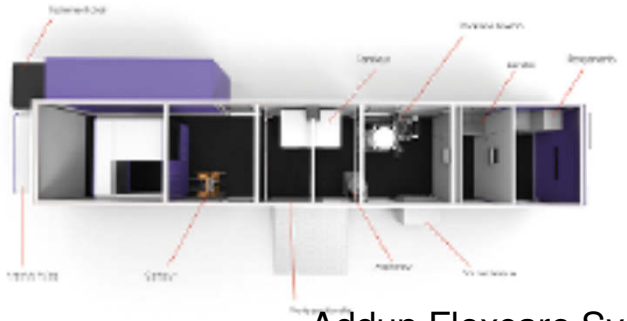
Magic 800, BeAM

ProX 300, 3D Systems

CONCLUSION

TO REMEMBER

- **AM equipment design**
  - To limit worker exposure to airborne particles → work closed door
  - To improve working conditions (handling, postures) → access to all the chamber areas
- **Premises design**
  - To prevent fire and ATEX risks
- **Safe-by-design process**
  - Working protocols



Addup Flexcare System™

- **Meanwhile: Collective and Personal Protective Equipment (CPE, PPE)**
  - CPE: local exhaust ventilation
  - PPE: non-woven coverall, mask with P3 filter, nitril gloves

THANKS FOR YOUR ATTENTION !

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