

SAfety BY Design Of nanoMAterials – From Lab Manufacture to **Governance and Communication: Progressing Up the TRL Ladder** 

# A control system solution to SAfety BY Design Of nanoMAterials

### Main Goal of the Project

New methodology and technology to address the existing challenges of Safety-by-Design (SbD) as a control tool for the production of safe(r) nanomaterials, i.e., addressing the SbD as a Control System Problem.

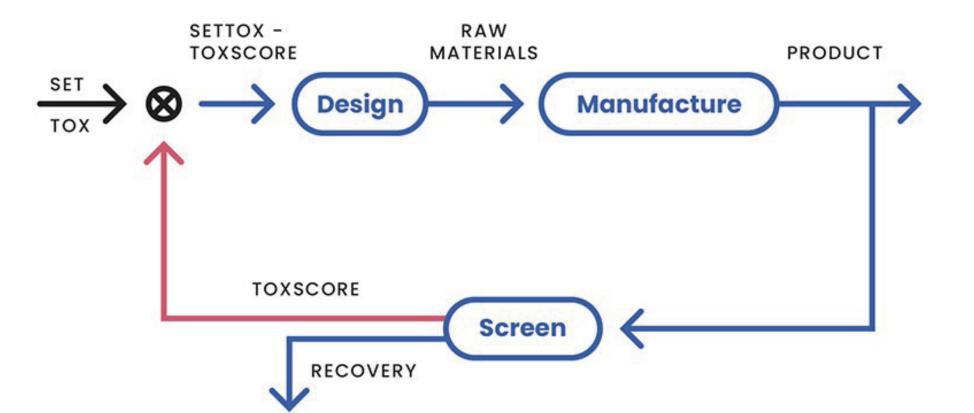
### **Industrial Case Studies**

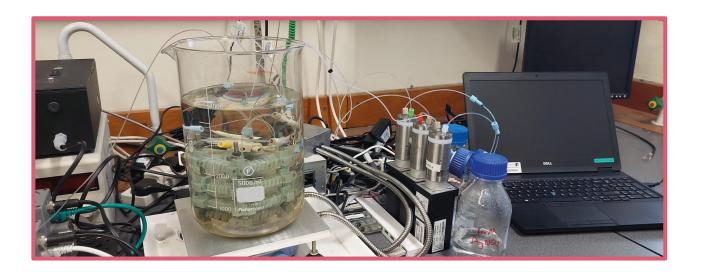
Case Study 1	Case Study 2	Case Study 3	Case Study 4
Safe Ag (and CuO) NP	Coated dental	Composite	Safe TiO2
colloids production	implants	electroplating	production

technologies developed within four industrial Case Studies involving the SbD production, use and function of engineered NM.

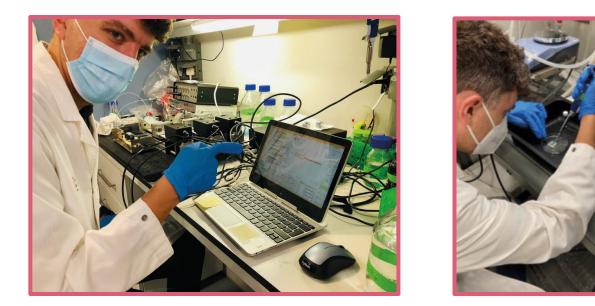
### **Project Outcomes**

Coupling rapid screening with online production to enable safe(r) nano-manufacture and advance materials. New technology & modelling approaches and SW for real world industrial applications: Demonstrator for online production of safe(r) nano.

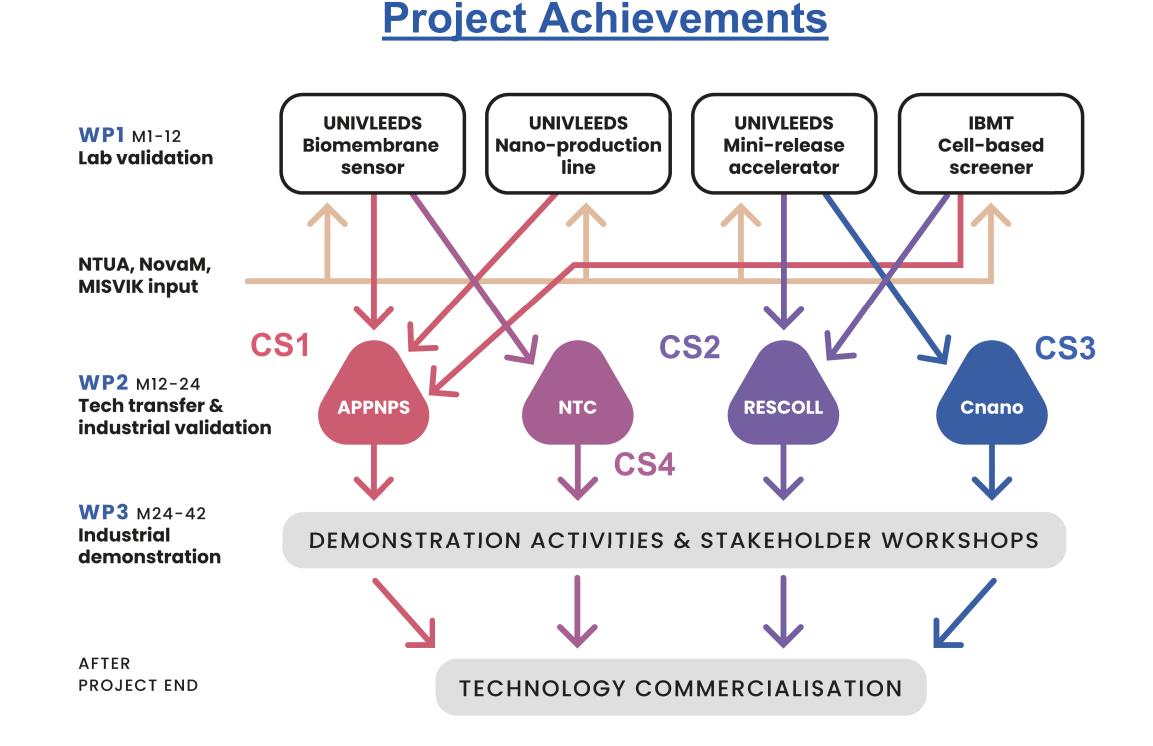




**Nano-Production line transfer** UNIVLEEDS > APPNPS – Aug. 2022



**Biomembrane sensor transfer UNIVLEEDS > APPNPS – May 2022** 



UNIVLEEDS – University of Leeds | APPNPS – Applied Nanoparticles S.L. Cnano – Creative Nano PC | NTC - NanoTechCenter LLC



### **Mini-Release Accelerator transfer UNIVLEEDS > RESCOLL – March 2023**



**Mini-Release Accelerator transfer** UNIVLEEDS > Cnano – Nov/Dec 2022



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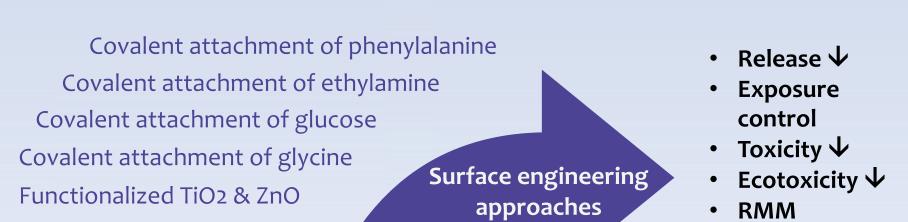


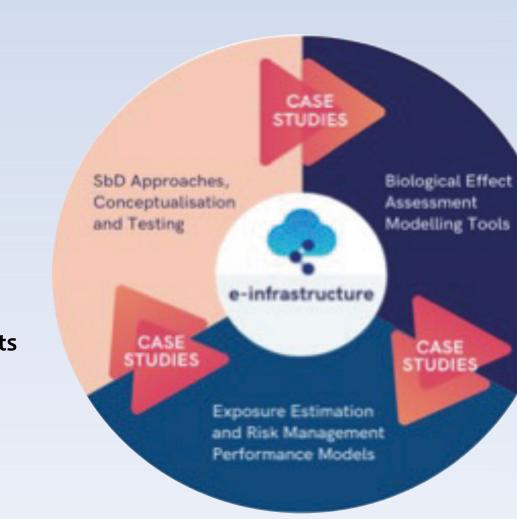
Computing infrastructure for the definition, performance testing and implementation of Safe-by-Design approaches in nanotechnology supply chains

# Our mission is to create an e-infrastructure for performance testing & implementation of Safe-by-Design approaches in the nanotechnology supply chain.

A major challenge for the global nanotechnology sector is the development of safe and functional engineered nanomaterials (ENMs) and nano-enabled products (NEPs). In order to minimise the risks to human and environmental health during the engineering of NEPs the goal of the SbD4Nano project is to create a novel e-infrastructure for the definition, performance testing implementation of Safe-by-Design (SbD) approaches in the and nanotechnology supply chains.

## **SbD proposed strategies**





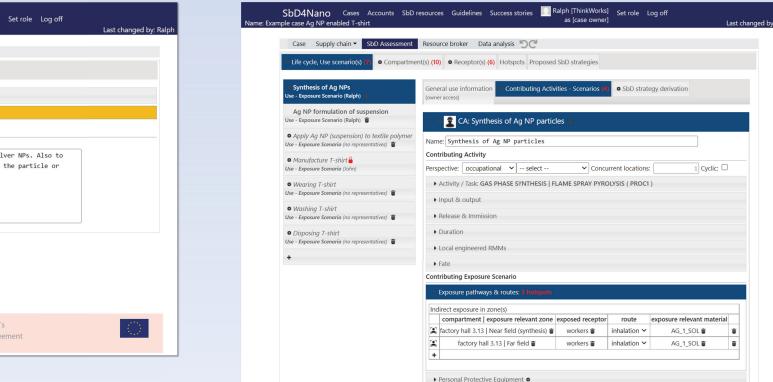
**SbD4Nano** will overcome all the barriers to promote the implementation of SbD approaches in the nanotechnology industry, providing SMEs with a set of web-based applications and tools.

## **E-infrastructure**

The "e-infrastructure" aims to foster dialogue and collaboration between actors along the nanotechnology supply chain for a knowledge-driven definition of SbD approaches based on hazard, exposure, product performance and cost criteria.

# 1. Case name and description. Accounts SbD resources Guidelines Success stories 🛄 Ralph [ThinkWorks] Set role Log off goal is to reduce potential hazards to workers during the synthesis and handling of the silver NPs. Also t nee the release of Ag NP particles due to washing. The idea now is to redesign the shape of the particle or

### 2. Information on the activity.



#### Functionalized SiO<sub>2</sub> NPs

implementation

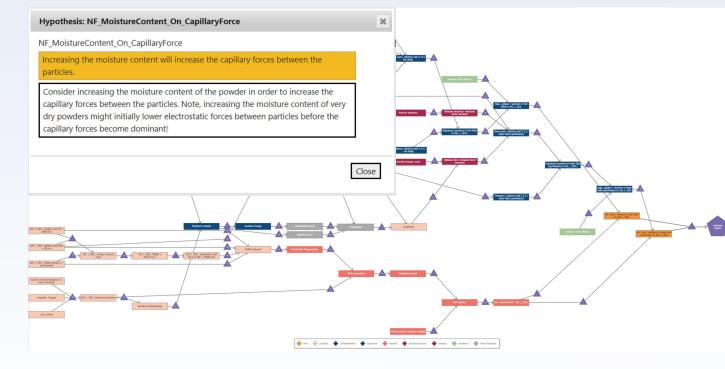
• Functional products

### **Engineered nanomaterials (ENMs)**

- Metal oxide nanoparticles (TiO<sub>2</sub>, ZnO)
- Core-shell silica nanoparticles
- Carbon nanofibers • Graphene oxide

The e-infrastructure is validated in case studies and then implemented at a larger scale to assist and guide industry, regulators, and civil society in the design of well-balanced safety, functionality and cost strategies.

#### 3. Influence diagram generated by the e-Infrastructure.



#### 4. Ranking of **SbD strategies** derived from the influence diagram.

Context	Strategies derived from influence diagram	Path
G_1_SOLworkers	I Inflammation, cytokine release	Cell viability 1   Inh. hazard limit : AG_1_SOL 1   inh. risk   workers in Near field (synthesis) to AG_1_SOL 1   workers health 1
Silver, Ag (s), EC=231- 131-3	modify core: Silver	AG_1_SOL: Surface chemistry I?   ROS generation?   Oxidative stress 1   Cell viability 1   Inh. hazard limit : AG_1_SOL 1   Inh. risk   workers in Near field (synthesis) to AG_1_SOL 1   workers health 1
Copper, Cu (s)	modify impurity: Copper	AG_1_SOL: Surface chemistry 1?   ROS generation?   Oxidative stress 1   Cell viability 1   Inh. hazard limit : AG_1_SOL 1   inh. risk   workers in Near field (synthesis) to AG_1_SOL 1   workers health 1
unidentified chemical?	modify Surface functionalization X   main chemical:	AG_1_SOL: Surface chemistry I?   ROS generation?   Oxidative stress 1   Cell viability 1   Inh. hazard limit : AG_1_SOL 1   inh. risk   workers in Near field (synthesis) to AG_1_SOL 1   workers health 1
AG_1_SOL	modify AG_1_SOL: shape category = scElongated	HARN stressor? I?   Frustrated Phagocytosis I   ROS generation J   Oxidative stress I   Cell viability 1   Inh. hazard limit : AG_1_SOL 1   inh. risk   workers in Near field (synthesis) to AG_1_SOL 1   workers health 1
AG_1_SOL	modify AG_1_SOL: shape category = scElongated	AG_1SOL: surface volume ratio 1?   AG_1SOL: MSSA = 400 m <sup>2</sup> g <sup>-1</sup> 1   AG_1SOL: dissolution half time in PSF = 6000 min 1   HARN stressor? 1   Frustrated Phagocytosis 1   ROS generation 1   Oxidative stress 1   Gell viability 1   Inh. hazard limit : AG_1SOL: 1 inh. risk   workers in Near field (synthesis) to AG_1SOL 1   workers health 1
AG_1_SOL	I AG, 1_SOL: particle diameter = 65-nm Reduction of the fibre diameter (preferably below 30nm) might make the fibres less rigid. (GRACIOUS HARN IATA) Conflict	HARN stressor? I [routrated Phagorytosis 1   ROS generation 1   Oxidative stress 1   Cell viability 1   Inh. hazard limit : AG_1_SOL 1   inh. risk   workers in Near field (synthesis) to AG_1_SOL 1   workers health 1
AG_1_SOL	1 AG_1_SOL: particle diameter = 65 nm Conflict	AG_1_SOL: surface volume ratio 1   AG_1_SOL: MSSA = 400 m <sup>2</sup> g <sup>-1</sup> 1   AG_1_SOL: dissolution half time in PSF = 6000 min 1   HARN stressor? 1   Frustrated Phagocytosis 1   ROS gener 1   Oxidative stress 1   Cell viability 1   Inh. hazard limit : AG_1_SOL 1   inh. risk   workers in Near field (synthesis) to AG_1_SOL 1   workers health 1
AG_1_SOL	t AG_1_SOL: particle diameter = 65 nm Conflict!	aerodynamic diameter = 130 nm 1 [gravitational force 1] settlement 1   dustrines 1   Release rate released silver particles 1   Zone conc. (thictory hall 3.13   Near field (synthesid) 1   Epocure (workers in Near field (synthesid) to AC_1_SOU 1   rep. uptake   workers in Near field (synthesid) to AC_1_SOU 1   wh. risk   workers in Near field (synthesid) to AC_1_SOU 1   workers hall 1
AG_1_SOL	1 AG_1_SOL: median size D3 = 6000 nm Shorter fibres (preferably below 5 µm) reduce the HARN charateristics. (GRACIOUS HARN IATA)	HARN stressor? 1   Frustrated Phagocytosis 1   ROS generation 1   Oxidative stress 1   Cell viability 1   Inh. hazard limit : AG_1_SOL 1   inh. risk   workers in Near field (synthesis) to AG_1_SOL 1   workers health 1
AG_1_SOL	1 AG_1_SOL: median size D3 = 6000 nm	AG_1_SOL: surface volume ratio 1   AG_1_SOL: MSSA = 400 m <sup>2</sup> g <sup>-1</sup> 1   AG_1_SOL: dissolution half time in PSF = 6000 min 1   HARN stressor? I   Frustrated Phagocytosis I   ROS gener 1   Oxidative stress I   Cell viability 1   Inh. hazard limit : AG_1_SOL 1   inh. risk   workers in Near field (synthesis) to AG_1_SOL I   workers health 1
AG_1_SOL	t Hamaker const.	van der Waals force 1   coagulation 1   dustiness 1   Release rate: released silver particles 1   Zone conc. (factory hall 3.13   Near field (symthesis) 1   Exposure (workers in Near field (symthesis) to AG_1_SOL) 1   resp. uptake   workers in Near field (symthesis) to AG_1_SOL 1   workers health 1
AG_1_SOL	1 Mointre context Lovering the moliture context of the powder may eventually leed to increased electrostatic forces between particles in case the powder becomes yery dry. Note: Lovering the moliture context might also reduce capitary forces between the particles before the electrostatic forces become commany.	electrostatic forer 1 [ cogylation 1   fauthese 1   Relase rate released silver particles 1   Zone conc. (factory hal 313) Near field (synthesid) 1   Eposure (norkers in Near field (synthesid) to AG_1.50U 1   resp. uptake   workers in Near field (synthesid) to AG_1.50U 1   inh. risk   workers in Near field (synthesid) to AG_1.50U 1   workers health 1
AG_1_SOL	1 Molance content. Consider increasing the molature content of the powder in order to increase the capillary forces between the particles. Note, increasing the molature content of very dry powders might initially lower electrostatic forces between particles before the capillary forces become dominant Conflict.	capillary force 1 [ capilation 1 [ duriness 1] Befases enc relaxed tive particles 1] Zore conc. (Encrory hall 3.13] Narr field (synthesis) 11 [ Dysource (notass in Near field (synthesis) to AG_150L 1] workers in Near field (synthesis) to AG_150L 1] workers beath 1
AG_1_SOL	t skeletal density = 4.9 cm <sup>-9</sup>	aerodynamic diameter = 130-nm t   gravitational force t   settlement t   dustiness i   Reease rate released silver particles   Zone conc. (factory hall 3.13   Near field (synthesis)) i   Eposure (workers in Near field (synthesis) to AG_1_SOL i   resp. uptake   workers in Near field (synthesis) to AG_1_SOL i   workers hall h.t.
Synthesis of Ag NP particles	t workers: RPE efficacy Start using respiratory equipment or use ones with higher efficacy.	resp. uptake   workers in Near field (synthesis) to AG_1_SOL 1   inh. risk   workers in Near field (synthesis) to AG_1_SOL 1   workers health 1
Synthesis of Ag NP particles	t workers: RPE efficacy Start using respiratory equipment or use ones with higher efficacy.	resp. uptake   workers in Far field to AG_1_SOL 1   inh. risk   workers in Far field to AG_1_SOL 1   workers health 1
Synthesis of Ag NP particles	1 Automatization level 5) increasing the level of activity/process automation the number and/or duration of manual interventions is lowered and as such the necessity of human presence is reduced.	Presence. (factory hall 3.13 [Near-field (synthesid) 1   Epopoure (workers in Near-field (synthesid) to AG_1_SOL) 1   resp. uptake   workers in Near-field (synthesid) to AG_1_SOL 1   inh. workers in Near-field (synthesid) to AG_1_SOL 1   workers health 1
Synthesis of Ag NP particles	t Automatization level By increasing the level of activity/process automation the number and/or duration of manual interventions is lowered and as such the necessity of human preserves in reduced	Presence. (factory hall 3.13   Far field) 1   Exposure (workers in Far field to AG_1_SOL) 1   resp. uptake   workers in Far field to AG_1_SOL 1   inh. six   workers in Far fi

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