

E. Keim (AREVA NP GmbH) - J.-P. Van Dorselaere (IRSN)

NUGENIA R&D ON SAFETY ISSUES PERSPECTIVES IN THE DOMAINS OF AGEING AND OF SEVERE ACCIDENTS

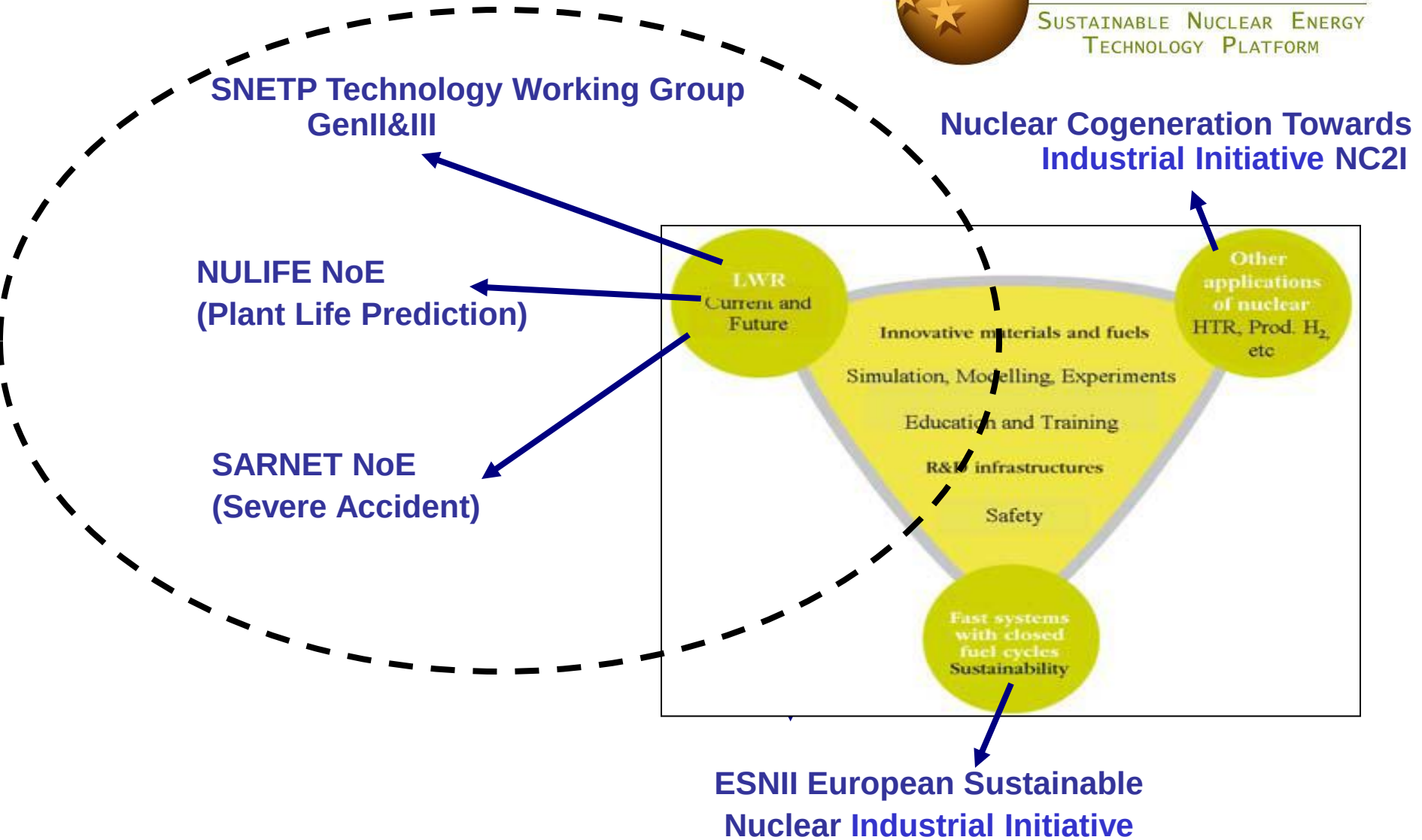
Contents

- SNETP and NUGENIA
- Focus on NULIFE outcomes on R&D priorities for materials ageing
- Focus on SARNET outcomes on R&D priorities for severe accidents
- NUGENIA perspectives

Part I

SNETP and NUGENIA

One of the 3 pillars in SNETP



What is NUGENIA

- International non-profit making association according to Belgian legislation 1921: established Nov 14, 2011
- SNETP mandates NUGENIA to act as the body in charge of coordinating at EU level the implementation of the R&D within Gen.II&III technical scope, thus for tasks:
 - Define detailed R&D roadmaps and priorities
 - Facilitate the emergence of projects implementing Gen.II-III R&D
 - Identify all relevant funding sources for R&D
 - Generally promote European nuclear Gen.II-III collaborative R&D
 - Facilitate cooperation with international counterparts on Gen.II-III R&D
- NUGENIA today:
 - About 60 organizations of diverse types (utilities, vendors, research, TSO, universities).
 - End-users' group (utilities, TSO).

- Integration of projects and expertise developed in Europe:
 - NULIFE, ENIQ, SNETP TWG Gen II&III, SARNET...
- Objective of implementation of R&D projects:
 - Simple proven project creation process, issued from NULIFE
 - Efficient coordination across 8 technical areas.
- R&D current roadmap in 8 technical areas, based in two of them on NULIFE and SARNET outcomes → *Following illustration of R&D priorities for the topics:*
 - Materials ageing (part of area N°4),
 - Severe Accidents (globally area N°2).
- Interactions with FORATOM R&D, ETSON, IAEA, OECD, ENEN, ENEF...

NUGENIA technical areas

Portfolio Assessment Group (G8)

Technical Areas

1	Plant safety and risk assessment
2	Severe accidents
3	Core and Reactor performance
4	Integrity and ageing of SSC
5	Fuel, waste and dismantling
6	Innovative Gen III design

SARNET
inputs →

NULIFE
inputs →

E

N

I

Q

H
A
R
M
O
N
I
S
A
T
I
O
N

Part II

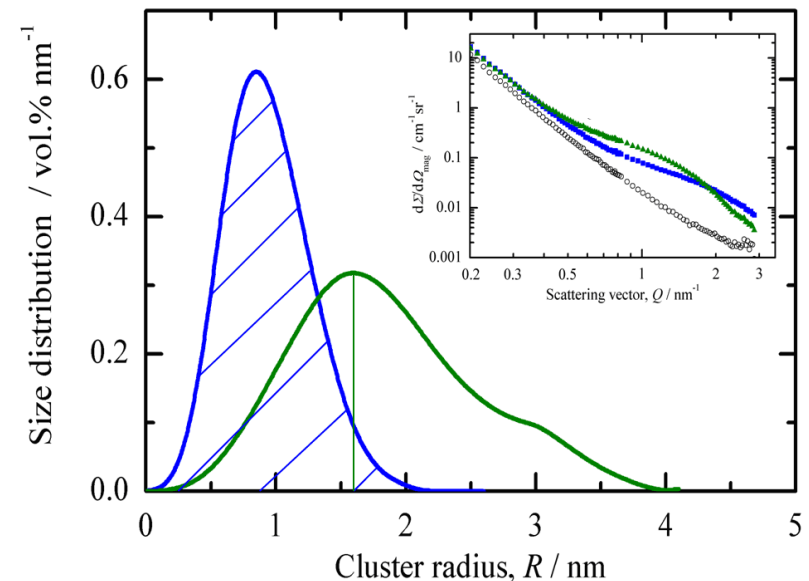
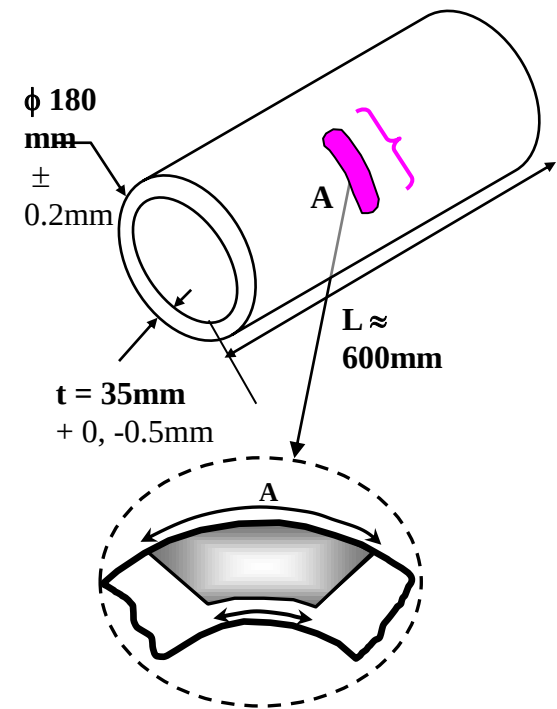
Focus on NULIFE outcomes on R&D priorities for materials ageing

NULIFE (NUclear Plant LIFE Prediction)

- Network coordinated by VTT from 2006, transformed in an Association in 2011.
 - Main objectives:
 - Create a sustainable Europe-wide forum in order to achieve the scientific and technical excellence in residual lifetime prediction methodologies,
 - Translate methodologies into harmonised and qualified procedures as part of the Common Safety Justification Framework,
 - Consolidate network position as the lead forum for representing European research interests,
 - Become a recognised RTD service provider for end-users.
- *Virtual organisation capable of providing harmonised R&D in the area of lifetime evaluation for the nuclear power industry and the relevant safety authorities.*

Two examples of FP7 NULIFE umbrella projects

- **STYLE** (Structural integrity for lifetime management – non RPV components), coordinated by AREVA NP GmbH,
 - Example of mock-up 2 aged austenitic pipe containing a repaired butt weld: thermal ageing at 650°C, pre-fatiguing and fracture tests in 2013.
- **LONGLIFE** (Treatment of long-term irradiation embrittlement effects in RPV safety assessment), coord. by HZDR,
 - Good progress on development of multi-scale based models,
 - Example of effect of fluxes on cluster radius at RPV weld material (**blue curve**= flux 35 times higher / **green**).



- Material properties:
 - Reliable material properties for extended service and creation of a radiation embrittlement database ($\Rightarrow$ improved trend curve for RPV life assessment evaluations),
 - Treatment of corrosion and environmental-fatigue data,
 - Effect of manufacturing processes (welding, thermal and mechanical treatments and coatings) on materials and properties.
- Ageing mechanisms:
 - Better knowledge of corrosion, fatigue, irradiation embrittlement, stainless steel cracking and concrete ageing,
 - In case of very long times of operation (possibly > 60 years), need to address ageing mechanisms previously considered as lesser importance, such as creep and thermal ageing.

- Modelling of ageing:
 - Need of modelling improvements for a better physical understanding of all relevant ageing mechanisms and their driving parameters:
 - Identify not only the thresholds for defect initiation and the kinetics for defect propagation, but also the precursor state that leads to defect nucleation.
 - Need of reliable long-term predictions of ageing and its effects ⇒ modelling fundamental phenomena in physics and chemistry at different scales from atomic to macroscopic.
 - Need of validation of model parameters vs. data from laboratory experiments or operating experience feedback.

Part III

Focus on SARNET outcomes on R&D priorities for severe accidents



Severe
Accident
Research
NETwork of excellence



1st project 2004-2008 in FP6

2nd project started in April 2009 for 4 years in FP7

Both under **IRSN coordination**

Work $\approx$ 40 equivalent full-time persons/year

Budget $\approx$ 9 M€/year

Today:

- **24 countries** (Europe, Canada, USA, Korea, India, Japan)
- **47 organizations of diverse types** (TSO, safety authorities, research, industry, vendors, universities)
- **230 researchers** (+ $\approx$ 30 PhD)

Ranking of SA R&D priorities (1/2)

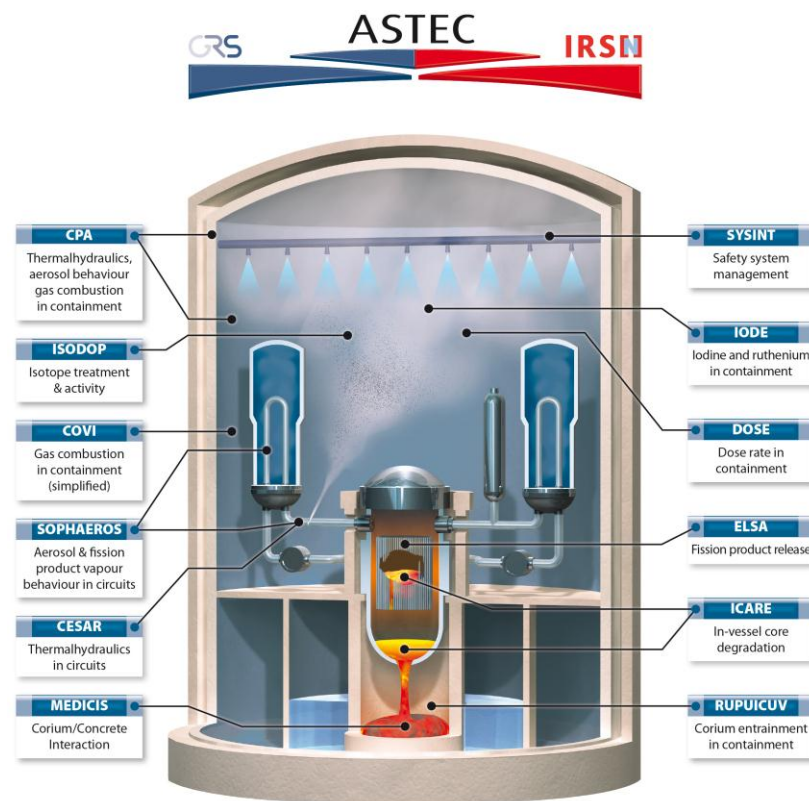
- SARP (SA Research Priorities) group,
 - Composed of experts, including end-users (utilities, TSOs...),
 - On-going and “living” process, based on PIRT approach.
- ⇒ ***6 issues with high priority that were used in 2008 to structure the SARNET FP7 project :***
 - Core coolability during reflooding and debris cooling,
 - Ex-vessel melt pool configuration during Molten-Core-Concrete Interaction & ex-vessel corium coolability by top flooding,
 - Melt relocation into water & ex-vessel Fuel-Coolant-Interaction,
 - Hydrogen mixing and combustion in containment (flame acceleration),
 - Oxidising impact on source term (Ruthenium oxidising conditions, air ingress for high burn-up and MOX fuel elements),
 - Iodine chemistry in circuits and in containment.

- The SARP group has updated in 2012 the R&D priorities, using as information sources:
 - Results of on-going SARNET FP7 work packages,
 - ASAMPSA2 project in FP7 on PSA2 best-practices,
 - OECD Projects (BIP, THAI, MCCI...).and accounting for the 1st feedback of the Fukushima accidents.
- Main conclusions of the update:
 - Only a few changes on the 2008 ranking: the 6 highest-priority remain open despite large progress in understanding (and closure of a few sub-issues),
 - In relation with Fukushima, **some SA topics get higher relevance and a few new issues need to be addressed.**

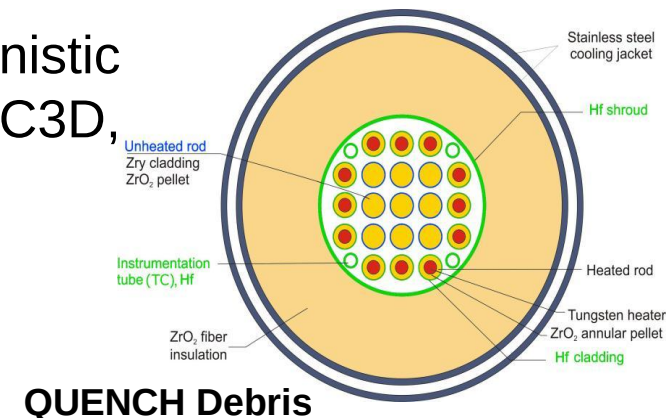
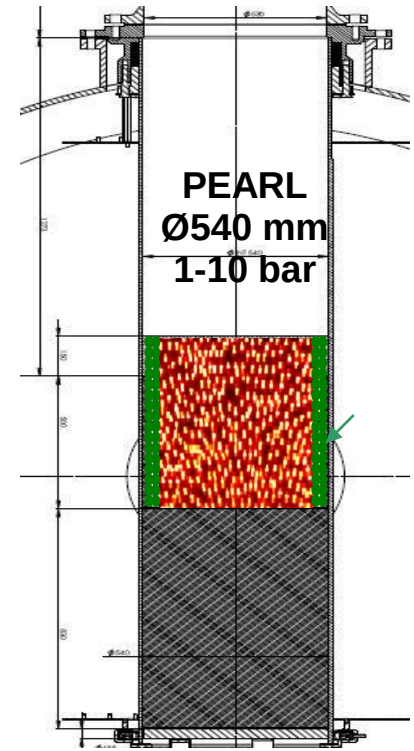
Evolution of R&D priorities after Fukushima

- *Most physical phenomena in Fukushima were already considered in SARNET as high-priority subjects.*
- Globally more attention to mitigation of consequences for a case of inefficient accident prevention:
 - H₂ explosion, melt/debris coolability, containment venting/filtering...
 - Increase from medium to high priority for two phenomena:
 - Integrity of RPV due to external vessel cooling: improve data base for critical heat flux and external cooling conditions,
 - Corium coolability in lower head: Improve predictability of the thermal loading on RPV lower head to maintain their integrity.
 - Efforts must increase on issues that were not intensively addressed in SARNET:
 - Pool scrubbing under boiling conditions,
 - Behaviour of spent fuel pool scenarios,
 - Instrumentation ad-hoc for SA diagnosis.

- The Fukushima accidents underlined the need of improvement of BWR-specific models and associated validation against existing experimental data and future experiments.
- Also need to improve the capability of codes (integral codes + CFD) to simulate the SFP behaviour.
- Capitalisation of knowledge will continue in ASTEC (IRSN-GRS) integral code:
 - Acceleration of adaptation of core degradation models to BWRs under way by IRSN.



- **Debris bed formation and coolability:** several complementary experiments (1D or 2D, shape of debris bed, particle shape, BWR conditions...),
 - PRELUDE and PEARL (IRSN), QUENCH-Debris (KIT), POMECO-HT (KTH), DEBRIS (IKE Stuttgart), COOLOCE (VTT), ⇒ *already showed an increased coolability / earlier understanding and 1D past experiments*
 - Improvements under way of mechanistic (ATHLET-CD, ICARE/CATHARE, MC3D, JEMI-3D...) and ASTEC codes,



QUENCH Debris

Part IV

NUGENIA perspectives

NUGENIA perspectives

- NULIFE and SARNET have brought their significant expertise and R&D work on integrity and ageing of SSC and on severe accidents.
- Roadmap under review, to be included in the SNETP Strategic Research Area update in Feb.2013.
- Objective of wider membership (Europe and out), in particular to continue the active collaboration with non-European actors (e.g. SARNET current partners).
- Strong and coordinated portfolio of collaborative projects ensuring that the R&D provides the partners/members with recognised value.
- NUGENIA+ answer to FP7 EC call 2013, coordinated by VTT, on the preparatory phase for integration of national programmes at the European level.

Acknowledgements



- *To the European Commission for funding the SARNET and NULIFE networks in FP7*
- *To the governing bodies and partners of the NoE SARNET and NULIFE*
- *To the SARP group and in particular its leader, W. Klein-Hessling (GRS)*