Nuclear Technologies for Sustainable Development

Martin Ruščák
September 13, 2017
WHY... to secure nuclear knowledge?

Safety and longevity of current operation

Sustainable power supply for the 21st century

It’s about carbon....
Shares of different technologies / 2050 2DS scenario

WHAT... do we need?

- Critical mass of engineers
- Demanding tasks
- Superb technical competencies
Knowledge Infrastructure in Nuclear Technologies in the Czech Republic / Czechoslovakia

- Ability to build & operate:
  - A-1
  - 4x VVER 440 Dukovany
  - 2x VVER 1000 Temelín

- Regulation:
  - SONS

- Research:
  - RR VVR-1
  - RR LR-0
  - UJV privatized
  - Research Centre
  - Intermediate storage

- Education:
  - Nuclear faculty
  - Nuclear technologies at other universities

- Interim storages of spent fuel

- Timeline:
  - 1950
  - 1960
  - 1970
  - 1980
  - 1990
  - 2000
  - 2010
  - 2020

The Czech Republic: Research Related Assets

- **People**
  - Since 1955 four generations of nuclear engineers: Pioneers of 50/60s, Power stations builders of 70s/80s, Operators of 90s/00s, New technologists of 2000+
  - High public support
  - High expertise in most of nuclear technology fields

- **Knowledge**
  - R&D related to the current NPPs: Nuclear safety – deterministic & probabilistic, component integrity, back end of fuel cycle, engineering
  - R&D related to Generation IV
  - R&D related to fusion technologies
The Czech Republic: Research Related Assets

- **Infrastructure**
  - Research reactors (LVR-15 & LR-0 in Řež, VR-0 at the university)
  - Hot cells
  - Loops
  - Material research labs

- **Major knowledge-based Institutions**
  - UJV (Nuclear Research Institute)
  - CVR (Research Centre Řež)
  - UJP (Institute of Nuclear Fuels)
  - FJFI (Faculty of Nuclear and Physical Engineering)
  - SUJB (regulator)
  - SURAO (waste treatment)
  - SURO (State Institute of Radiation protection)
Principle issues targeted in the Czech nuclear energy research / in CVR
WHY – WHAT - HOW

**Needs**
- Support the Czech national technology strategy
- Create a cutting edge for the UJV Group
- Maintain, foster and grow the nuclear related knowledge base

**Drivers**
- EU/ worldwide need for innovations in power generation
- Economical success
- Young professionals

**Enablers**
- Cutting edge technologies
- Research reactors
- Tradition in nuclear research in Czechia
- Support by the State
- EU support
- International cooperation

- Sustainable Energy (SUSEN): 95 M EUR to expand the technologies
- Staff: 300+
- Cutting edge technology issues: Gen II, III, III+, Gen IV, Fusion, Hydrogen
- Publications
- Young scientific generation
- International networking
Research Centre Řež - R&D focus

**Generation 2, 3 reactors**
- Material research
- Fuel assessment
- Water chemistry
- NDE related research

**Generation 4**
- Supercritical PWR
- HTGC He cooled
- Fast - He cooled
- Fast - Pb-Bi cooled
- MSR

**Special projects**
- Fusion ITER
- Material R&D JHR
- Nuclear waste back end research
- Hydrogen energy
Research Centre Řež: Infrastructure

10 MWt research reactor LVR15
- Irradiation
- Irradiated material testing
- Fuel and spent fuel testing

Critical assembly: LR 0

Material testing & microstructure

Hot cells

Experimental loops:
- HT He,
- PB, PB-Bi
- Super critical H2O
- Super critical CO2
- VVER

Fusion primary first wall high heat flux testing
The most important SUSEN technologies

Materials and components

- Gen II, III
- Gen IV Fusion

Safety, design, processes

- Materials
- Design
- Processes

RAW and the environment

- RAW densification and separation
- Cold crucible
- LOCA chamber
- Gamma irradiation
- Salt loop
- HTH Loop
- SCW Loop
- Allegro Loop
- SCO2 Loop
- Cf source
- HML
- n-source 14 MeV
- TBM mock up

Testing

- Non/active mechanical testing lab
- Active TEM, SEM microscopy, microanalysis
- Hot cells: specimen preparation, testing, microanalysis

Testing, 20MW/m2

PFW & Divertor
Creating opportunities for the young generation: Portfolio of projects

- Materials and components
- Thermal Hydraulics and Processes
- Neutronics
- Waste and Environment

Gen II, III Gen IV Fusion

Materials and components:
- PWR: RPV steels degradation
- Corium phase studies
- NDT exfol
- Turbine blades degradation

Thermal Hydraulics and Processes:
- LHM – materials interaction tests
- Cross valve ALLEGRO
- T-H for LHR
- Neutronics FLIBE

Neutronics:
- FHR / MSR: reactivity
- F4E: materials & radiation

Waste and Environment:
- Materials for final depository
- RAW – fluoride extraction
- SCW material testing

Fusion:
- Eurofusion Safety
- Industrial application
- R&D for future technologies
- National grants
- H2020
- R&D projects outside EU
- Commercial projects
- Internal CVR projects

Industrial application
R&D for future technologies
National grants
H2020
R&D projects outside EU
Commercial projects
Internal CVR projects
How: Synergies & International networking

NUGENIA
EERA
SNETP
ENEN
ETSON

JHR

Large volume / low power research reactor LR-0

10 MW material testing reactor LVR-15

Gen II, III
Mat & SSC
Ageing & LTO
Qualifications

GEN IV
Development
Materials
Safety

RAW
Fusion
Final disp
Separation
Env
PFW heat flux
TBM maint
Mat testing

JRC, CEA, ORNL
& other R&D Institutions in Europe & Worldwide

ÚJV

How: Synergies & International networking

NUGENIA
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JRC, CEA, ORNL
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ÚJV
Activities and capabilities of UJV Rez in the area of nuclear power

September 2017
Karel Křížek
Outline of the presentation

• UJV history
• UJV Group
• Activities and capabilities of UJV
• Examples of references
UJV Rez - Significant milestones

1955  Foundation of the Nuclear Physics Institute in Rez
1957  VVR-S research reactor start-up – with capacity of 2 MWt
1993  The Nuclear Research Institute Rez was privatized to joint-stock company
2000  Purchase of Institute of Applied Mechanics Brno
2002  Foundation of the Research Centre Rez
2002  Purchase of part of ENERGOPROJEKT PRAHA (foundation 1949)
2009  Acquisition of Research and Testing Institute Plzen (foundation 1907) and EGPI
2012  Change of trade name from Nuclear Research Institute to UJV Rez
2017  Merging UJV with EGPI (one of subsidiary companies)
2017  SUSEN Project - starting the operation of research infrastructures
UJV Group – 1300 employees

UJV is a group of companies providing:

- research and development,
- design, engineering services,
- production of special products and facilities,
- expert activities in the power, industry, and health sectors.

Shareholders

Subsidiaries

Institute of Applied Mechanics Brno
Research Centre Rez
Research and Testing Institute Plzen
International cooperation - inherent part of activities since UJV foundation in 1955

**Multilateral cooperation**
- International Atomic Energy Agency (IAEA), Vienna
- Nuclear Energy Agency (NEA), Paris
- EURATOM Framework Programmes
- Member of the Sustainable Nuclear Energy Technology Platform (SNETP)
- Member of the European Nuclear Education Network (ENEN)
- Member of the European Technical Safety Organisations Network (ETSON)
- EPRI, ....

**Bilateral cooperation**
- Alternative Energies and Atomic Energy Commission (CEA), France
- Institute for Radiological Protection and Nuclear Safety (IRSN), France
- Gesellschaft für Anlagen-und Reaktorsicherheit (GRS), Germany
- Czech-Russian Working Group for Nuclear Energy, MPO/ROSATOM, Rusko
- State Scientific & Technical Centre for Nuclear and Radiation Safety, (SSTC NRS), Ukraine
- Cooperation with US institutes through US NRC and DoE
- Bhabha Atomic Research Centre, India
- Electric Power Research Institute, USA
- and others
Main activities of UJV
Design, engineering and analytical support of NPP

Complex support of UJV Rez for Nuclear Power Plants
Safety analysis
- Safety analysis and support for the licensing

Monitoring and diagnostics
- Advanced methods for diagnostics of components and systems

Reactor physics and fuel cycle support
- Nuclear reactor core reload designs

Reliability and risk analysis
- Reliability and risk analyses of complex technologies - probabilistic methods

Severe accident analysis and fuel thermo-mechanics
- Severe accidents analyses, development of accident management procedures, proposals and verification of measures to improve safety
Integrity and technical engineering

Integrity assessment and technical engineering for NPPs safety and lifetime

Tests, analyses and evaluation of energy equipment materials and environment
- Evaluation of microstructural and micro-chemical properties of irradiated and non-irradiated materials
- Evaluation of operational damages (corrosion, stress, …)

Calculations, analyses, design basis
- Support and development of NPP lifetime management process
- Calculations of pressurized thermal shocks and piping systems

Tests and evaluations of mechanical properties of materials, hot laboratories and irradiation experiments
- Evaluation and prediction of reactor pressure vessel service life, taking into account properties of reactor pressure vessel material and fluencies

Non-destructive methods of equipment surveillance and qualification

Qualification of materials and equipment for radiation and aggressive environment
Fuel cycle chemistry and waste management

Radwaste management
- Services and technologies for processing of RAW
- R&D and testing of matrixes and technologies
  - Bitumen, cement, geopolymer and mixture matrix
  - Cold crucible, molten salt oxidation, nano-structures application

Decommissioning of nuclear facilities and workplaces with ionizing sources
- Licensing documentation
- Decontamination and segmentation technology
- Waste processing
- Clearance monitoring after decommissioning

Research and engineering support for deep geological disposal
Barriers development and testing:
- Corrosion, diffusion, chemical interactions
- Anaerobic conditions, radionuclides migration
- Hydrogeology models, modelling
Design and engineering services

- Studies and technical assistance
- Permit documentation
  - Site permit, construction permit, EIA
- Tender documentation
- Consultancy and technical services
- Owner’s engineer services
- Basic design
- Detailed design and engineering services
  - Project coordination
  - Elaboration of selected parts of detailed design
  - Author’s supervision during the construction
  - As-built documentation
- Technical support services for nuclear authorities
- Data processing and related services
Radiopharmaceuticals

Research, development, manufacturing and quality control

- PET radiopharmaceuticals, SPECT radiopharmaceuticals
- Three PET centres operating, staff training

PET = Positron Emission Tomography
Examples of references
Recent design activities in Czech Republic

**Temelín NPP – Unit 1, 2**
- Design basis for replacement of I&C systems
- Technical support during operation
- Study for preparation of NPP decommissioning
- Radioactive waste management
- Design of spent nuclear fuel storage
- Cooperation on power uprate
- “Stress test” measures
- GADUS – development and implementation of special SW for operation support

**Dukovany NPP – Unit 1 - 4**
- Study of Dukovany power uprate
- “Stress test” measures
- Spent Fuel Storage design
- Long term operation support

**New Temelín NPP – Unit 3,(4)**
- Feasibility Study
- Technical cooperation on tender doc.
- Local partner for suppliers
- EIA, analysis of related investments

**New Dukovany NPP unit(s)**
- New power unit feasibility study
- EIA, analysis of related investments
Recent design activities in Slovakia

**MOCHOVCE NPP Unit 1,2**
- General designer
- Power uprating of units
- Design of stress test measures

**MOCHOVCE NPP Unit 3, 4 – under construction**
- General designer
- On site author´s supervision
- Basic Design and “stress test” measures
- Detail Design – internal connecting piping, electrical systems and emergency supply
- Independent design review

**EBO V2 NPP**
- Power uprating of units
- Safety upgrading measures

**New NPP JASLOVSKE BOHUNICE**
- New power unit feasibility study
- Participation in EIA study
Nuclear safety and reliability

- Development and applications of advanced algorithms for optimisation of fuel loading in NPPs
- Safety analysis for power uprating projects for Czech NPPs Dukovany and Temelin
- Safety analysis for updating of Safety Analysis Reports for operating NPP
- Independent verification of safety analysis for foreign NPP (Finland, Slovakia)
- Application of severe accident analysis for NPP safety enhancement
- SCORPIO system – monitoring of the core parameters (Dukovany)
- Accumulation of energy in hydrogen, development & operation of hydrogen bus
Integrity and technical engineering

- Continuous demonstration of integrity of reactor vessels and reactor coolant system
- Development of long-term operation and lifetime extension of Czech NPPs
- Development of the long-term operation and plant life management strategy for the Ukrainian nuclear power plants
- Evaluation of the technical conditions and lifetime extension of the reactor pressure vessel and internals Ukrainian NPPs
Fuel cycle chemistry and waste management

RAW Management

- Complex services including collecting the waste at the customer’s and transfer
- Processing and solidification of RAW (90% of institutional RAW in CR)
- Decommissioning, fragmentation and decontamination

Transport of spent fuel from research reactors

- Executed shipments from countries: Czechia, Poland, Ukraine, Belarus, Serbia, Hungary, Bulgaria, Vietnam, Uzbekistan, Georgia, Ghana

Permanent deep geological repository in the CR

- Lead technical advisor to the national RAW disposal authority SURAO
South - Ukraine and Rovno NPP

- Successful prolongation of reactor operation Unit 1 South-Ukraine NPP (VVER 1000/302)
- Expected prolongation of the reactor operation of Rovno NPP – Unit 3
  - Preparation of the new licensing documentation – strength and lifetime
  - Design of the new life time management program
- Enhancement and recalculation of the number of operational regimes Unit 1 and 2 Rovno NPP (VVER 440)
Strategy for long-term operation of NPP in Ukraine

- Customer: NAEK Energoatom
- UJV is a leader of consortium
- Evaluation and recommendations for improvements of existing methodological documentation for ageing management
- Development of 12 ageing management programmes for 12 pilot equipment of South Ukraine and Zaporozhie NPP
  - Reactor pressure vessel and internals
  - Steam generator
  - Body of main circulation pump
  - Spent fuel pool
  - Containment tendon system
Approach to Implementation of services

- Compilation of Licensing Basis Documentation, including implementation of post Fukushima measures
- Development of criteria for evaluation of compliance of construction licence documentation with requirements for nuclear safety and radiation protection
- Independent safety analyses of accidents
- The result of R&A is the Evaluation Report of PSAR and other construction licence documents
- SW tool developed for support to safety evaluation – LBAT
# NPP Hanhikivi 1200 MW, Finland

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<th>Information</th>
<th>Details</th>
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<tr>
<td><strong>Hanhikivi NPP</strong> VVER-1200 PWR reactor AES-2006, Finland</td>
<td>![旗] Fennovoima Oy, Finish corporation ![旗] ![旗] Rosatom Overseas</td>
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**Scope of ÚJV services:**
Independent evaluation of Preliminary Safety Analyses Report, support for fuel licensing, development of severe accident simulation model, complex analysis of fuel rod inventory

**Related activities:**
Organizing and participating in international seminar of the Czech and Finnish nuclear regulatory authority focused on licensing of the new NPP.
Contacts

Address:
Headquarters: UJV Rez, a. s., Hlavni 130, Rez, 25068 Husinec, Czech Republic
www.ujv.cz

THANK YOU FOR YOUR ATTENTION
The European Commission’s science and knowledge service

Joint Research Centre
Nuclear Technologies for the 21st Century Conference

Maria Betti
European Commission, JRC, Directorate G for Nuclear Safety and Security, Director
Řež, 13 September 2017
The JRC within the Commission

28 Commission Members

Jean-Claude Juncker
President

Tibor Navracsics
Education, Culture, Youth and Sport

Vladimír Šucha
Director-General, Joint Research Centre

Strategy & Coordination
Knowledge Production
Knowledge Management
Support
Directorate G Organisational Chart

**Dep. I: Nuclear Safety**
- Jean-Paul GLATZ, Karlsruhe

**GI.4. Nuclear Reactor Safety & Emergence Preparedness**
- Michael FÜTTERER, Petten

**GI.5. Advanced Nuclear Knowledge**
- Roberto CACIUFFO, Karlsruhe

**GI.6. Nuclear Safeguards and Forensics**
- Rudy KONINGS, Karlsruhe
- Klaas LÜTZENKIRCHEN, Karlsruhe

**GI.7. Nuclear Security**
- Stefan NONNEMAN, Ispra

**GI.8. Waste Management**
- Joseph SOMERS, Karlsruhe

**GI.9. JRC Nuclear Decommissioning**
- Paolo PEERANI, Ispra

**G1. Radioprotection and security**
- Vincenzo RONDINELLA, Karlsruhe

**G2. Standards for Nuclear Safety, Security & Safeguard**
- Ralph MAIER, Karlsruhe
- Willy MONDELAERS, Geel

**Dep. II: Nuclear Security and Safeguards**
- Willem JANSSENS, Ispra

**Dep. III: Nuclear Decommissioning**
- Vincenzo RONDINELLA, Karlsruhe

**G10. Knowledge for Nuclear Safety, Security and Safeguards**
- Franck WASTIN, Petten

**Staff Dir. G at the JRC sites = 465**

- **Karlsruhe** 44%
- **Ispra** 36%
- **Geel** 11%
- **Petten** 10%
Policy & Strategic Context

- Job, Growth and investment
- Energy Union and Climate
- EU as a Global Actor

ENERGY UNION PACKAGE
COM(2015) 80 final

EU Member States
International Partnerships

International Atomic Energy Agency (IAEA)
European Nuclear Safety Regulators Group (ENS:REG)
European Commission
Consilium
European Parliament
Industry, Research and Energy
Scientific and Technical Committee (STC) Euratom
Advisory Board JRC BoG
EU Member States
NEA OECD
Nuclear Energy Agency
Dir. G Nuclear Safety and Security
EEERA
IGD-TP
European Nuclear Energy Forum
International Forum
SNETP
### Protecting Society

**Dimensions:** Competitiveness, Resilience, Fairness  
**Nexus:** Energy and Transport, Education, Skills and Employment  
**Technical Areas:**  
- Safety of current systems  
- Waste Management  
- Safeguards and Non-Proliferation

### Fostering Sustainability and Decarbonisation

**Dimensions:** Competitiveness, Resilience, Fairness  
**Nexus:** Energy and Transport, Resource Scarcity, Climate Change and Sustainability  
**Technical Areas:**  
- Safety of future and innovative systems  
- Fuel Cycle and Waste Management

### Strengthening Global Partnership

**Dimensions:** Resilience, Fairness  
**Nexus:** Civil Security  
**Technical Areas:**  
- Nuclear Security  
- Safeguards and Non-Proliferation

### Promoting Reversibility: back to the green field

**Dimensions:** Competitiveness, Fairness  
**Nexus:** Energy and Transport, Education, Skills and Employment  
**Technical Areas:**  
- Nuclear Decommissioning and Environmental Remediation

### Broadening Knowledge and Competence

**Dimensions:** Competitiveness, Fairness  
**Nexus:** Education, Skills and Employment

**Technical Areas:**  
- Nuclear Science Application  
- Nuclear Knowledge Management
Safety of Current and Innovative Systems

- Long-term Operation and Operational Safety
- Fuels and Materials for Gen II and III reactors
- Reactor Design Extension Conditions Modelling and Assessment
- Safety of Advanced Nuclear Systems and Innovative Fuel Cycles
- System Analysis of Emerging Technologies
- Knowledge for nuclear Safety and Policy Support

Security, Safeguards and non-proliferation

- Innovative and Remote Safeguards
- Enhanced Nuclear Materials Measurements
- Methods, Data and knowledge management for Nuclear Non-Proliferation, Safeguard and Security
- Strategic Trade Control
- Nuclear Forensics and Detection of Illicit Trafficking of Nuclear and (other) Radioactive Materials
- CBRNEsec

Decommissioning, Environmental Remediation and Waste management

- Decommissioning and remediation of Damaged Reactors: their cores and sites
- Innovative Techniques/Technologies and standardisation of Practice
- Safety of spent and damaged fuel
- Waste from innovative fuel
- Managing Decommissioning and Waste Management Knowledge

Nuclear Science Applications

- Basic properties of radionuclides and associated applications
- Accelerator based nuclear data measurements and associated applications

European Commission
Synergies complementarities and cooperation with the SUSEN (SUSTainable ENergy) regional R&D centre infrastructure
Děkuji za pozornost

Any questions?
You can find me at maria.betti@ec.europa.eu
Innovation in Nuclear for a Sustainable Energy Future

Daniel IRACANE
Deputy Director-General and Chief Nuclear Officer

Scientific conference
“Nuclear Technologies for the 21st Century”

Research Centre Rez – 13 September 2017
The NEA: 32 Countries Seeking Excellence in Nuclear Safety, Technology and Policy

- Foster international co-operation
- Forging common understandings
- Conduct multinational research
Bringing together Governmental Officials and Experts

Steering Committee for Nuclear Energy

CSNI
Committee on the Safety of Nuclear Installations

CNRA
Committee on Nuclear Regulatory Activities

RWMC
Radioactive Waste Management Committee

CRPPH
Committee on Radiation Protection and Public Health

NLC
Nuclear Law Committee

NDC
Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle

NSC
Nuclear Science Committee

MBDAV
Management Board for the Development, Application and Validation of Nuclear Data and Codes

75 working parties and expert groups

21 international joint projects
• e.g. the Halden Reactor Project operating for several decades

60 publications and reports per year
Challenges for a sustainable energy future

- No need to recall that
  Energy is and will stay a vital worldwide sector
  - 1.2 billion people without access to electricity
  - 2.7 billion people without clean cooking facilities
  - From 7.5 billion people today to 10 billion in 2050
  - 6.5 million premature deaths per year due to air pollution
  - In the power sector, a strong drop in carbon intensity by 2050
    (533 ➔ 40 gCO₂/kWh) to fit with the 2°C scenario
  - Energy investments: 1 800 G$ = 2.4% of global GDP2015
    • Nuclear energy current investment 21 ➔ 110 G$/y for the 2°C scenario
For most countries, Energy Policy is driven by three Top Level Objectives

- Environment
- Sustainability
- Reliability/Security of Supply
- Economics

What investment in research and innovation for Nuclear being part of the solution?
Regarding economics: market conditions are challenging nuclear technology

- **Cost of Nuclear versus Coal & Gas**
  - Cheapest option at 3% discount rate
  - Slightly cheaper at 7%
  - More expensive at 10%

- **Evolution impacting nuclear competitiveness**
  - Increase share of shale gas without carbon pricing
  - Cost of Renewables
  - System Cost

- **Innovation is necessary to improve at the same time Safety and Competitiveness of nuclear technology**
Regarding security of supply and reliability

- For nuclear technology by such: □

- For the global energy system level: increased flexibility needed
  - due to the high penetration rate of Variable Renewable Energy

- Innovation is requested to develop efficient load follow, SMR, co-generation, etc.
To be part of the solution, nuclear technology has to innovate

Improving cost effectiveness and flexibility

AND

Enabling further enhancements to safety at lower cost

Assuring that nuclear fits in the future global energy framework, by definition uncertain and changing.
Nuclear Innovation 2050: Identifying Key Nuclear R&D Needs and Innovation Pathways

• What technologies will be needed in 10 years? 30 years? 50 years?

• What R&D is needed to make these technologies available?

• How do we regain the ability to push innovation into application?
NI2050, developing new cooperative approaches at the multinational level

- To develop multilateral consensus on promising innovation target areas and priorities
  - Identification of opportunities, gaps, existing background

- To establish solid common foundations based on scientific validation
  - Utilisation of state-of-the-art knowledge & modelling, infrastructures and experimental technology

- To define shared qualification methods to support robust licensing processes
  - “Safety built in” at the early stage in the innovation design
NI2050 Process for Accident Tolerant Fuel
How to reduce cost/risk/timeline for development?

- Inviting labs and industry
  - To identify few promising technologies that will meet the needs
  - To consolidate a sound and share understanding on the state-of-the-art for infrastructures, experimental technology & modelling

- Inviting regulatory bodies and TSOs to increase their co-operation on promising technologies
  - International co-operation allows early insight in safety aspect of innovations without compromising regulatory independence

- Inviting labs and TSO to exchange on sound and manageable qualification testing
Research infrastructures are the cornerstone of this process

- Investments in research infrastructures are mandatory

- In this perspective, SUSEN is an asset for the future

- To develop multinational experimental programs
  - Providing sound and robust basis to the new technologies
  - Providing activity maintaining research infrastructure performance
  - Increasing young generations’ interest and long term involvement
Nuclear Technologies for the 21st Century?

- For many countries, Nuclear will be a tool for meeting top-level objectives in a sustainable energy policy.

- A mandatory condition: keeping Nuclear Technology “alive” through a continuous innovation process...
  ... like for any other technology ...

- Entering in a new world:
  - From 60’s / 70’s model driven by strong national strategy
  - To Multilateral approaches of the innovation process creating shared confidence in new technologies, opening the international market, and attracting investment and young generations
Thank you for your attention

All NEA publications and institutional documentation available at www.oecd-nea.org
New Centre for Nuclear Safety at VTT

Vice President Satu Helynen, VTT

Nuclear technologies for the 21st century
UJV, September 13, 2017
VTT Technical Research Centre of Finland Ltd

75 years' experience in supporting our clients' growth with top-level research and science-based results.

VTT is one of the leading R&D&I organisations in Northern Europe.

We provide expert services for our domestic and international customers and partners, both in private and public sectors.

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www.vttresearch.com,
vttpeople, @VTTFinland

36% of Finnish innovations include VTT expertise.*

VTT is the most important public research partner for Finnish companies.

In 2016, VTT was the most active patent applicant in Finland.

Net turnover and other operating income
269 M€ (VTT Group 2016)

Unique research and testing infrastructure

Personnel 2,414
(VTT Group 2016)

Wide national and international cooperation network

Nuclear energy R&D competencies and resources

- VTT has 200 experts and scientists in nuclear energy backed up with competent staff in other departments
- VTT research competencies cover
  - Reactor safety
  - Future reactors
  - Waste management
  - Fusion
- VTT’s annual revenue of nuclear activities is approx. €25 million
- VTT performs contracted research on challenging topics related to nuclear safety, plant life management and nuclear waste management
New Centre for Nuclear Safety was inaugurated in 2016
Ready for increased international collaboration with R&D community and companies

National Finnish research programmes
The Finnish Research Programme on Nuclear Power Plant Safety SAFIR 2018

EU-funded research
-Currently e.g. TeamCables, NOMAD, ATLAS+, MEACTOS

Jules Horowitz Reactor – project
(partners e.g. EDF, Studsvik, UJV, CIEMAT, Areva…)

EU-NOMATEN (VTT-CEA-CNBJ)
Center of excellence in multifunctional materials for industrial and medical applications

Nuclear Waste
Disposal network in Finland and Sweden
-Posiva, SKB, Fortum, TVO, Fennovoima, STUK, etc...

Alliance networks for irradiated material studies
-EERA, NUGENIA, NKS, …

Scientific national collaboration with
- Aalto University,
- Lappeenranta University of Technology,
- Helsinki University,
- University of Eastern Finland,
- Geological Survey of Finland,…

Nuclear Materials
Reactor materials testing and research for safe operation

- VTT has been hosting the national hot laboratory infrastructure since it was first constructed and equipped in the 1970’s.
- Principle use has been for handling, testing and examining RPV materials for surveillance testing.
- Many critical plant life management issues for operating nuclear power plants are related to materials.
- Lifetime extension, power upgrading, and construction of new plants require investigating and solving problems related to components and structural integrity (e.g. EPR, AES2006, SMR).

- Aging degradation of structures and components is an important aspect of power plant safety.
- Ageing management requires activities related to the utilization, inspection, surveillance, testing, examination, and degradation mitigation of materials.
The VTT Centre for Nuclear Safety

- **2,360 m² laboratory wing**: a basement level and two floors of laboratory space.
- Basement mainly for storage and handling of radioactive materials and waste.
- Laboratory space arranged around a main high-bay, which houses the hot-cells proper:
  - mechanical and microstructural characterisation of materials
  - Radiochemistry & dosimetry
  - HR-ICP-MS
  - iodine filter testing
  - nuclear waste management
  - failure analysis
VTT Rad Materials Services Ecosystem: R&D in Support of Nuclear Power Industry

- BASIC RESEARCH & NUMERICAL SIMULATION
- EXPERIMENTAL DATA EXPERTISE
- POST-IRRADIATION EXAMINATIONS
- SINGLE EFFECT EXPERIMENTS
- CODES Validation
- QUALIFICATION Documents
- DESIGN
- MANUFACTURING REFABRICATION CHARACTERIZATION
- Hot laboratories for PIE
- Material Test Reactor
- Hot laboratory

20.9.2017
VTT nuclear energy R&D competencies
Radioactive Waste Disposal Solutions

- Characterization of radioactive waste
- Operating waste and decommissioning
- Design of disposal concept (KBS-3)
- Operating waste and decommissioning
- Bedrock and groundwater characterization
- Long-term safety of materials, disposal facilities and safety case
- Engineering barrier system component manufacturing and quality control
- Operational safety of disposal facilities, incl. PRA
- New and alternative waste management technologies
- Licensing support
- Low and Intermediate waste storage.
The VTT Centre for Nuclear Safety

- 3,300 m² office wing includes a ground-level conference centre, and three floors of modern, flexible office space for 150 people.
- Altogether VTT has ca. 200 experts and scientists connected to nuclear energy studies.
- Excellences included:
  - computerized fluid dynamics
  - process modelling (APROS)
  - fusion plasma computations
  - severe accidents
  - core-computations
  - waste-management
  - safety assessments
C-class laboratory
C-class laboratory

Nuclear Waste Management

- Spent fuel dissolution studies (UO$_2$ and ThO$_2$)
- Decommissioning waste studies ($^{14}$C)
- Bentonite studies
- Copper corrosion studies

High resolution sector field ICP-MS (inductively coupled plasma mass spectrometer)

- Quantitative or qualitative analysis of 75 elements
  mg/L $\rightarrow$ ng/L $\rightarrow$ pg/L ($10^{-12}$g/L)

  Not for H, C, N, O, F and noble gases
Experimental Source Term Analysis – Aerosol physics laboratory

- Several methods to generate gaseous and aerosol compounds
- Several analysis methods for gaseous and aerosol samples
  - FTIR, ICP-MS, ELPI, BLPI, CPC, DMA, SMPS, TEOM, LIQUISCAN-ES, filters, bubblers, etc.
- A specific network of analysis services for particles/solid samples
  - Including e.g. SEM, TEM, RAMAN, XPS, XRD, UV-Vis (soluble samples)
- Flow/temperature/pressure controlling and monitoring devices
B- and A-class laboratory
Main floor B-laboratory: Nuclear waste & radiochemistry

- $\alpha$-glove-box (small underpressure) for working with $\alpha$-active radionuclides
- General chemistry laboratory equipment
- Movable laminar-flow cabinet (e.g. microbiology)
- Possibility to install another $\alpha$-glove-box
- Lockable storage room for nuclear materials

Main floor A-laboratory: Pilot area

In the high-bay, partly sectioned off.
Equipped with e.g.
- Fume hood
- Glove-box (small over pressure)
  - Argon atmosphere, low contents of $O_2$ (<0.1 ppm) and $CO_2$
- Cabinet for chemicals
- Gamma-cell- Dose rate 6.4.2017 60,22 Gy/h
Hot analytical microscopy
Hot specimen preparation for microscopy

- Several options for specimen preparation in the CNS, $f(\gamma)$
  - Heavily shielded- HC1, 370 GBq Co$^{60}$
  - Shielded glovebox- HC2, 1,85 GBq Co$^{60}$
  - Devices in plexiglass containments

Metallographic sample preparation

- Optical microscope
- Digital stereo microscope
- Grinding / polishing
- Electropolishing / thinning
- Accessories
  - ultrasonic bath, magnetic stirrer, hot plate, air dryer, vacuum chamber, punch, etc.
Analytical Scanning Electron Microscope

- Fracture surface topography
- Microstructure characterisation
- Element distribution mapping
- Compositional analysis of corrosion products

Analytical Scanning/Transmission Electron Microscope

- Manifestation of neutron irradiation effects
- High resolution microstructural imaging
- Crystallographic information
- Nano-scale elemental distribution mapping
A-Class Hot Cell laboratory
A-class hot cell facilities for handling activated metals

Mechanical testing
• Tensile
• Impact
• Fracture toughness
• Crack growth rate
• Hardness

Fabrication procedures
• Electrodischarge machining
• Electron beam welding
• Mechanical sawing & milling

Microscopy
• Grinding, polishing, etching
• Light microscopy
• Dimension measurements

Special purpose test set-ups
• Biaxial creep (fuel cladding)
• Corrosion in simulated LWR
Basic HC design features

• Space limiting liner
  – Provides containment
    • Contamination space
    • Manipulator reach area
    • Enables under-pressure
    • Gloved maintenance ports

• Biological shielding
  – Provides $\gamma$-radiation protection
    • Design source term $3700 - 370 - 1,85\text{GBq \, Co}^{60}$ (HC3-HC1-HC2)
    • Front wall lead thickness $250 - 200 - 100 \text{ mm (HC3-HC1-HC2)}$
    • Lead windows with equivalent thickness
    • Maintenance doors, rear

• Steel frame
  – Support structure for liner, shielding and cover plates
Summary of VTT irradiated materials competences

- Portfolio of radiochemistry, nuclear waste management, aerosol methods
- Long experience in irradiated materials testing, particularly RPV surveillance specimen fracture mechanical testing
- Demonstrated capability for producing custom in-core testing devices
- Core member of the Jules Horowitz materials testing reactor
- New Centre for Nuclear Safety offers broad portfolio of irradiated materials mechanical testing, analytical microscopy and radiochemistry.
TECHNOLOGY FOR BUSINESS
The Key role of Research Reactors in support to the development of nuclear energy: example of the JHR project, a new Material Testing Reactor working as a European and international User’s Facility in support to Research Institutes and Nuclear Energy.

Dr Gilles Bignan, Dr Franck Gabriel

French Atomic and Alternative Energies Commission

Research Centers Cadarache & Saclay (France)

Corresponding author: gilles.bignan@cea.fr
Neutron beam reactors with high neutron flux beams (CNS: Cold Neutron Source)
- High neutron fluxes to investigate matter and help establish fundamental laws
- Basic science
- Neutronography
- Radioisotopes

Technological irradiations reactors (MTR: Material Testing Reactor)
- R&D to study Fuel and Material Behavior under irradiation
- Production of radioisotopes (MOLI)

Physic reactors (LPR/ZPR Low/Zero Power Reactors)
- Neutron physics
- Reactor core physics (code qualification)
- Instrumentation/Calibration
- Criticality and safety issues

Reactors dedicated to Safety research programs

Reactors for Education & Training (E&T)
A bit of history for France…
35 Research Reactors constructed (civil purpose) from 1948 until 1980
One idea → one reactor (golden age !)

From ZOE (1948-1976) To Jules Horowitz Reactor (JHR) (2021 → > 2070)
A BRIEF HISTORY OF RESEARCH REACTORS IN FRANCE

Massive building activity between the 50’s and the 70’s who help a lot developing national nuclear infrastructure:

- Neutron studies for Reactor Core Physics
- Education & Training
- Material science (fuel and structure behavior under irradiation)
- Safety studies
- Fundamental research on matter…

Then due to various Reasons (Lack of Programs and/or Funding, Safety Reassessments leading to significant Refurbishment works-compliance with upgraded Safety Rules…) \( \rightarrow \) Strong rationalisation of Research Reactor fleet (Costs/Benefits Analysis)
7 RR operated in France (6 by CEA – 1 by ILL) in a broad range of activities:

- 3 Zero Power Reactors for reactor physics studies
- 1 dedicated reactors for safety experimentation
- 2 neutron beams reactors for fundamental research
- 1 Education & Training Reactor
Core physics:

- Refurbishment of MASURCA (Gen 4)
- Phase-out of EOLE&MINERVE (Gen2&3) → new project ZEPHYR

- Safety dedicated Research Reactor: Refurbishment of CABRI

- Neutron beams Reactors for fundamental research: ILL

- Material Testing Reactor: JHR
Same story in USA…example of INL:
50 research reactors built in Idaho: only 2 in operation today!
Example: Safety Dedicated Research Reactor
The CABRI reactor to study RIA (Reactivity Initiated Accident)

Fast valves

\[ P_{\text{He-3}} < 15 \text{ bars} \iff \rho < 4 \]$
CABRI Massive Refurbishment: Example of seismic reinforcement
Now let’s talk about Material Testing Reactors
The Key-Role of Material Testing Reactors for Fuel and Material qualification under irradiation: R&D in support of Nuclear Power Industry

- **BASIS RESEARCH & NUMERICAL SIMULATION**
- **EXPERIMENTAL DATA EXPERTISE**
- **POST IRRADIATION EXAMINATIONS**
- **SINGLE EFFECT EXPERIMENTS**
- **MANUFACTURING REFABRICATION CHARACTERIZATION**
- **DESIGN**

**Material Test Reactor**

**CODES Validation**

**QUALIFICATION Documents**

**EXPERIMENTAL DATA EXPERTISE**

**Hot laboratories for PIE**
France Strategy for Material Testing Reactor: the future JHR as an International Users Facility

(contribution from Nicolas Waeckel – EDF/SEPTEN)
For EDF, 73 NPPs (France & UK) to operate means more than 12,000 Fuel Assemblies under irradiation at the same time...

... in an aggressive environment, for more than 6 years:

Limiting cases:

- Normal operation
- Class 1 - 4 transients

To avoid “bad surprises” the operator wants the fuel to be carefully designed, with enough Safety Analysis Design Margins.

- FGR, Creep & Growth, clad T, ..
- Too much power (SCC-PCI, RIA, ..)
- Not enough cooling (LOCA, Dry-out, ..)

In-pile data required!
From tests results to Design Margins assessment (and reverse)

- In-reactor Experience
- Separate effect tests
- Models, Tools, Design limits, Methods
- Simulation (Class 1 to Class 4 transients)
- Design Margins
- Safety Case Analysis Files
- Out-of-pile tests
- In-pile tests
- Regulators
Safety case analysis → Safety margins

- New Fuel managements
- New LWR std
How to generate additional margins to accommodate these issues?

Mainly 3 lever arms

1. **Improve Modeling, Calculation tools and Testing (MTR)**
2. Improve Safety Analysis design Methods
3. **Improve Fuel Product** (eg E-ATF to be qualified under relevant conditions (qualification process = 10-15 years))
MTR allows to reproduce on a small scale (100 MWth) representative in reactor test conditions for:

- Material screening
- Material characterisation
- Fuel element qualification

CEA is developing experimental devices for material studies under irradiation in normal or accidental conditions.

The appropriate answer to the Industry needs: JHR Project.
The Genesis of JHR within the European MTR context

Age of current E.U. main MTRs in 2016 (years)

- BR2 (B) 54
- HALDEN (N) 59
- HFR (NL) 56
- LVR 15 (CZ) 60
- MARIA (PO) 43
- OSIRIS (F) 50 (shut down)

Under construction:
1. R&D in support to nuclear Industry
   - Safety and Plant life time management (ageing & new plants)
   - Fuel behavior validation in incidental and accidental situation
   - Assess innovations and related safety for future NPPs

2. Radio-isotopes supply for medical application
   - $^{99}$Mo production
     - JHR will supply 25% of the European demand
       (today about 8 millions protocols/year)
     - Up to 50% upon specific request

3. A key tool to support expertise
   - Training new generations (JHR simulator, secondees program)
   - Maintaining a national expertise staff and credibility for public acceptance
   - Assessing safety requirements evolution and international regulation harmonization
JHR OPERATING RULES
JHR International Consortium

JHR consortium gathers organizations which take part financially in the construction of JHR (1 representative / organization)

JHR Consortium current partnership: Research centers & Industrial companies

In some cases, the organization (member of the JHR consortium) is itself the representative of a national domestic consortium which gathers organizations among industry, R&D organizations, TSO, or Safety Authority
JHR : an International Users Facility

**Governing Board**
(JHR Consortium Members)

**CEA**
(Nuclear Operator)

**Project leader**

**JHR Reference Operation Plan (4 years plan)**
For Members of the Consortium and Non-Members

- Proprietary Programs
- Joint international Programs(open to non-members) especially through EC/FP and/or OECD/NEA Joint Projects

**Project leader appointment**
Validation of operation plan, business strategy, economy of the project

Nuclear safety ; Technical and Economical performance (operation cost)

Operation plan fulfilment programs definition (preparation of next Operation Plan with users)

Thanks Jiri for your 8 years as chairman
JHR Building site
Recent photos (Mid 2017)
JHR construction update
(Mid 2017)

Civil work of Reactor
Building and Auxiliary Unit
Building nearly completed

Delivery of Hot Cells
end of 2016
(Czech partners)

Preparation for pool
liner setting-up
Small Cells – before installation of doors

Thanks Martin for the slides....
Doors for Hot Cells (installation of rotating)

- Manufacturing of doors at ACPP
  
  *Digulleville France*

  - 5 rotating and 4 sliding doors
  - Doors were on critical path of construction
  - Successfully installed on site in 09/2016
  - Completion planned from 10/2017
IN-FACTORY MANUFACTURING: PROGRESS ON KEY-PRIMARY-CORE COMPONENTS

- Horse saddle flange
- Main water box with primary system connection
- Last welding on the vessel
  Electron beam welding
- Casier for fuel elements
- Heat Exchangers (Spanish partner)
JHR design and performances:
First fleet of experimental Devices under development
&
Challenges and Innovations Associated
JHR: A Modern 100 MWth POOL-TYPE LIGHT WATER MTR OPTIMIZED FOR FUEL AND MATERIAL TESTING

- **Hot cells (non destructive examinations)**
- **Storage pools**
- **Reactor pool with examination benches**
- **Experimental cubicles and analysis laboratories**
- **About 200 aseismic pads**
- **Rooms devoted to reactor operation** (heat exchangers, primary pumps, safety systems, ...)
- **Rooms devoted to reactor operation** (control room, hot workshop, labs, ...)

**Reactor block**

- **JHR fuel element**
- **Core (Φ 70cm / h 60 cm) and Be reflector**
- **Water channels in Be reflector**
JHR Fuel qualification
(EVITA Program performed in BR2)
**JHR: experimental capacity & performances at 100 MW power level (*)**

(*) Maximum Power- Second Operating conditions: 70 MW

Thermal Neutrons flux

*In reflector*

JHR: $5.5 \times 10^{14}$ n/cm².s

and 6 displacement systems

---

Fast neutrons flux in core

JHR: $5.5 \times 10^{14}$ n/cm².s

---

**Material ageing**

JHR: up to 16 dpa/y

---

Displacement systems in JHR to:

- Adjust the fissile power
- Study transients

---

In JHR:

- Highly Instrumented Experiments
- On-line fission Gas analysis
- 20 simultaneous experiments

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OSIRIS MTR

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JHR MTR

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Hosting experimental systems (dedicated to LWR fuel testing)

LORELEI fuel testing under accidental conditions (LOCA)

- Source Term (FP releases)
- Rod thermal-mechanical behaviour
  - Ballooning and clad burst (fuel relocation)
  - Corrosion at high temperature
  - Quenching and post-quench behaviour

ADELINE
For fuel testing under off-normal conditions
Power transient, post clad failure fuel behavior, Lift-off experiment…

MADISON
For fuel testing under nominal conditions

IAEC In-Kind

EDF Support

CEA Support
- Irradiated material behaviour
  - tensile tests, resilience test (Charpy),
  - crack propagation tests ....
- Behaviour of Thermal affected zones

OCCITANE
For pressure vessel steel testing

CEA
Support

CALIPSO, MICA
For material testing
under high dpa
and accurate temperature control
(+ mechanical loading)
specimen for μ structure evolution, tensile test ; for 1 or 2 D creep tests ; for bending tests (stress relieving experiments) ;

CLOE Corrosion loop
for “Zr alloy Corrosion” and “Irradiation Assisted Stress Corrosion Cracking”

DAE
In-Kind

CEA
Support
JHR facility & experimental capacity

Non Destructive Examination (NDE) Benches

Sample examination in hot cells
Gamma and X-Ray tomography systems

Multipurpose test benches

Coupled Gamma & X-ray bench

Test device examination in pools
Neutron imaging system in reactor pool
Coupled X-ray & $\gamma$ bench in reactor pool
Coupled X-ray & $\gamma$ bench in storage pool

Neutron Imaging System

Initial checks of the experimental loading
Adjustment of the experimental protocol
On-site NDE tests after the irradiation phase

EDF Support

VTT In-Kind
System UGXR

- Target: to measure radionuclide distribution using gamma scanning/tomography or density distribution using X-ray scanning/tomography of the sample in the irradiation devise (e.g. ADELINE) in the reactor pool or storage pool

- Includes both hardware and software

- UGXR Bench and Collimators

- High safety and accuracy requirements
  - Positioning of the object and precision
  - Closing mandrel for the object
  - Total weight
  - Motorisation
  - Underwater movements
  - X-ray camera container placement
  - Unloading the bench in case of failure
On the importance of the instrumentation developed in an international context for answering needs coming from advanced simulation then enhancing the quality of the future JHR experiments...
Fast Neutron Detection System

FNDS is the first and unique acquisition system able to provide an online measurement of the fast neutron flux (E>1MeV) in typical MTR conditions.

FNDS has been validated in 2015 after successive tests at the Belgium BR2 reactor and at the French ISIS reactor (FNDS signal was compared to reference thermal and fast neutron flux measurements using activation dosimeters).

→ FNDS proved its ability to measure online both thermal and fast neutron flux with an overall accuracy better than 5% (2 sigma).
Fission gas analysis: Acoustic measurements

10-year development

Online measurement of the molar mass of the gas inside the fuel rod (\(\rightarrow\) fraction of released fission gas)

Operated successfully on a high burn-up MOX fuel rod in the REMORA-3 experiment (OSIRIS) & Excellent accuracy of the measurement (vs post-irrad. Meas.)
MELODIE: Mechanical Loading Device for Irradiation Experiments

Technical goals
- Study of LWR cladding irradiation creep
- Hoop stress 120 MPa, biaxiality ratio 0 to 1
- Biaxial online control of the stress
- Biaxial online measurement of the creep

Why
- New technology for future instrumented experiments in the JHR
- Anisotropic material calls for complex experiments
- Cladding life is multiaxial because of the combination of FGR and PCMI

First irradiation in Osiris performed in 2015 was very promising: optimisation of the device is going on

Creep rate @ 60 Mpa ≈ 4 μm/day
Creep rate @ 110 Mpa ≈ 8 μm/day
Preparing JHR International Community:
- The yearly seminar
- The Secondee Program
- The 3 Working Groups and the preparation of future joint programs (cf FIJHOP initiative)
- The recent ICERR designation by the IAEA
Preparing JHR International Community:

- **The yearly scientific and technical seminar**: possible participation for some non-members

- **3 Working Groups**:
  - Fuel R&D topics
  - Material R&D topics
  - Technology issues for experimental devices

← **Secondee Program**

- Compliance between future R&D needs and first experimental capacity
- Preparation of first JHR programs

Thanks Marek for chairing the Fuel WG!
THE 3 JHR WORKING GROUPS
ON FUEL, MATERIAL AND TECHNOLOGY

- R&D programs
- Joint programs (validation by the governing board)

International Advisory Group (not yet in existence)

- Device
- Sample holder
- Instrumentation
- PIE / PTE

Governing Board decision in 2012: establishment of 3 Working Groups on fuel, material and technology issues

- To provide recommendations and guidance regarding the reactor experimental capacity including hints on the facilities to be developed versus potential R&D needs and taking into account cost/benefit analysis

- To gather an international scientific Community for exchange of information and knowledge including scientific and technical seminars to identify and prioritize the topics of interest,
JHR WGs Road-Map: time frame and tasks

- Pre-JHR research programmes on selected fuel and material topics in current MTRs and hot labs
  - Experimental conditions representative for JHR
  - Possible qualification tests for some experimental devices of JHR
  - Learning to co-operate in programmes

Fuel and material WGs rank the research topics

WG proposals for first experimental campaigns for GB approval

Planning the first F & M programmes in existing MTRs and hot labs

2012

GB decision to establish WGs

2013-2016

Planning of the first actual JHR programme

2017-2020

Cost-benefit evaluation for different tests types (partly TWG task)

Operation of JHR and research programmes

2021-

Pre-JHR era: running pre-JHR programmes

FIJHOP

Last but not least: by confirming high scientific level in programmes, helping JHR project management to commercialise JHR capacity also to non-members
THE JHR AND ITS ANCILLARY FACILITIES AS AN “ICERR”

Fully compliant with the French Capacity Building Initiative based on 4 pillars:
- Human Resources Development
- Education & Training
- Knowledge Management
- Knowledge Network

IAEA ICERR labelling obtained on 14th September 2015

Strong CEA intention to welcome Junior and/or Senior Scientists, Nuclear Engineers, Operators, Safety Managers… within JHR teams for various topics (R&D programs, Hands-on training on equipments…)
To summarize….

1) Material Testing Reactors remains key-tools in R&D support for nuclear power industry

2) Research Reactors are now more “costly machines” than in the past...

3) The R&D is more and more mutualised and performed through international joint programs

4) Considering the increasing complexity of the experiments (due to enhanced requirements from simulation) the use of international platform (as will be JHR) is recommended

And Happy Birthday to LVR-15
Nuclear research in Slovakia

13. 09. 2017
Nuclear Technologies for the 21st Century
Peter Líška

www.vuje.sk
• Nucelar research in Slovakia officially started on 01. 01. 1977 when VUJE was established (state owned institute).

• In reality nuclear research started earlier when research department in NPP Jaslovské Bohunice was established – research activities for construction of the A1 reactor, the first reactor in former Czechoslovakia for production of electricity.
• Research activities for support of construction and operation VVER 440

• After division of former Czechoslovakia financial support decreased rapidly, but continued by government orders and research projects of Slovenské elektrárne company (SE, a. s.).

• After „privatization“ of SE, a. s., all support of nuclear research was canceled.
• New stage of research projects, new conditions, new relations, ...


• Domestic projects, strong EU influence – structural funds and others (Nuclear Regulatory Authority)

• List of agencies:
  - APVV – Slovak Research and Development Agency
  - VA – Research Agency
List of national projects

1. Zvyšovanie energetickej bezpečnosti SR
   – ASFEU, MŠVVaŠ SR (06/2010 - 12/2013)
2. Ochrana obyvateľstva SR pred účinkami elektromagnetických polí
   – ASFEU, MŠVVaŠ SR (01/2011 – 09/2015)
3. Zvyšovanie bezpečnosti jadrovoenergetických zariadení pri seizmickej udalosti
   – ASFEU, MŠVVaŠ SR (06/2012 – 10/2015)
4. Technická asistencia v oblasti jadrovej bezpečnosti
   – ÚJD SR (08/2013 – 07/2016)
5. Zabezpečenie elektromagnetickej kompatibility monitorovacích systémov mimoriadnych prevádzkových stavov jadrovej elektrárne
   – APVVV (07/2016 – 06/2020)
List of national projects

6. Rozšírenie platnosti výpočtových štandardov pre návrh seizmicky odolných nádrží naplnených kvapalinou, z hľadiska bezpečnosti v JE a iných priemyselných oblastiach
   – APVV (07/2016 – 06/2020)

7. Zvýšenie účinnosti prenosu elektrickej energie v PS SR
   – APVV (07/2016 – 06/2020)

8. Zvyšovanie energetickej bezpečnosti a efektívnosti SR
   – VA (07/2017 – 06/2022)

9. Výskum fyzikálnych a technických aspektov rýchleho plynom chladeného reaktora IV. generácie Allegro – dlhodobý strategický výskum; 40 mil. €, 6 rokov
   – VA (v procese)

10. Centrum excelentnosti Allegro
    – SAV
List of national projects

Helium Loop

Seismic Shaker
1. THERAMIN - Thermal treatment for radioactive waste minimisation and hazard reduction  
   - H2020 (06/2017 – 05/2020)
2. VINCO - Visegrad Initiative for Nuclear Cooperation  
3. ESSANUF - European Supply of SAfe NUclear Fuel  
4. CONCERT - European Concerted Programme on Radiation Protection Research  
   - H2020 (06/2015 – 05/2020)
5. PREPARE - Innovative integrative tools and platforms to be prepared for radiological emergencies and post-accident response in Europe  
   - FP7 (02/2013 – 01/2016)
6. ESNII PLUS - Preparing ESNII for HORIZON 2020  
   - FP7 (09/2013 – 08/2017)
List of EU projects

7. CESAM - Code for European Severe Accident Management
   - FP7 (04/2013 – 03/2017)

8. ASAMPSA_E - Advanced Safety Assessment: Extended PSA
   - FP7 (07/2013 – 12/2016)

9. NUCL-EU - Reinforcing the networking of FP7 National Contact Points
   and third country contacts in the Euratom Fission programme
   - FP7 (10/2009 – 12/2013)

10. NERIS-TP - Towards a self sustaining European Technology Platform
    (NERIS-TP) on Preparedness for Nuclear and Radiological Emergency
     Response and Recovery
    - FP7 (02/2011 – 01/2014)

11. SARGEN_IV - Proposal for a harmonized European methodology for
    the safety assessment of innovative reactors with fast neutron
    spectrum planned to be built in Europe
    - FP7 (01/2012 – 12/2013)
12. NC2I-R - Nuclear Cogeneration Industrial Initiative - Research and Development Coordination
   - FP7 (10/2013 – 09/2015)
13. CATO - CBRN crisis management: Architecture, Technologies and Operational Procedures
   - FP7 (01/2012 – 12/2014)
14. ALLIANCE - Preparation of ALLegro - Implementing Advanced Nuclear Fuel Cycle in Central Europe
   - FP7 (10/2012 – 09/2015)
15. SARNET2 - Severe Accident Research Network of Excellence 2
   - FP7 (04/2009 – 03/2013)
Thank you for your attention!
HIGHLIGHTS AND PERSPECTIVES OF THE CVŘ NUCLEAR RESEARCH

Vincenzo Romanello
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September 13th, 2017
Some Information about CVŘ

The Centrum výzkumu Řež s.r.o. (Research Centre Řež, CVŘ) was founded in 2002 as a subsidiary of ÚJV Řež, a. s. (previously Ústav Jaderného Výzkumu / Nuclear Research Institute, NRI).

Today CVŘ is employing 380 staff members.

In 2011, the LR-0 and LVR-15 research reactors were transferred to CVŘ.

A very important activity for CVŘ’s development, i.e. the SUSEN (SUStainable ENergy) project (funded by the EU Structural Funds since 2012) is oriented towards the knowledge economy.
Some Information about CVŘ

Two research reactors, set of experimental loops, microstructural and microchemical laboratories, NDE laboratory, neutron-physical and thermo-technical computation codes capabilities, design department, workshops and machinery park

Makes us able to participate in sophisticated research projects and participate in the development of new technologies for GEN IV, SMRs and nuclear fusion.

The company has developed broad-ranging relations with Czech, foreign and international organizations and participates in many projects together with companies, organizations and institutes from EU, USA, Japan etc.
Main Research Areas

Safe and Reliable Gen II&III Power Generation
Development of advanced knowledge and technologies for the safe and reliable nuclear power generation in current generation fleet (i.e. Gen II, III and III+).

Gen IV Technologies Development
Studies on lead, helium, molten salt and supercritical water cooled Gen IV reactors by means of experimental loops (some designed also for in-pile tests).

Fusion Technology Development
Testing and development of key components for nuclear fusion systems, support for the development of ITER and DEMO fusion reactor components.

Non-Nuclear Technologies
R&D on supercritical CO\textsubscript{2} technology, hydrogen production by high-temperature electrolysis, water management in power plants, concentrated solar power, NDT methods for diagnosing of energy generation equipment.
The main aims of the project are:

- to support the **safe, reliable and long-term sustainable** operation of existing nuclear power plants in view of extended lifetime

- to contribute to the transition from the **Gen II and III to the Gen IV** power generation technologies (through R&D);

- to significantly contribute to the **R&D** of advanced technologies for **thermonuclear fusion**.
Research Centre Řež has built an infrastructure which enables to solve complex issues arising from the development of innovative technologies in energy field.

The key objective of our research strategy is to exploit the synergies available in our infrastructure in order to develop excellences in relevant technology areas.

Examples:
- evaluation of materials degradation in various media and environmental conditions;
- testing of materials and components at high temperatures and heat fluxes;
- reactor physics experiments and irradiation services;
- nuclear fuel cycle studies.
Research Highlights – Some examples

Evaluation of Materials Degradation in Modelled Operation Conditions
Research Highlights – Some examples

Nuclear Fusion Technology R&D

- ITER
- HELCZA
- Test Blanket Module
- Research reactor LVR-15
- Heavy liquid metal loops

Calculations
Experiments
Testing
Evaluation

Materials development and testing
New chemical methods development
Maintenance methods development
Validations

Materials
Chemistry
Maintenance techniques
Research Highlights – Some examples

Extreme Heat Flux Material Testing

Thermal-hydraulic analysis

Design and calculations

Cooling media design and parameters

New materials design

Development

Testing

Evaluation

Analysis

Materials testing

Material changes and damage

Testing of chemically hazardous materials

NDE

Operation lifetime assessment

Analysis design and efficiency of cooling

TH codes benchmarking and verification

Optical microscopy
SEM
TEM
Microanalysis
SIMS
Nanoindent
Research Highlights – Some examples

Nuclear fuel cycle studies

- Final disposal development
- GEN IV development projects
- NPP radioactive waste issues
- Anaerobic and geotechnical labs
- Optical microscopy (SEM, TEM), microanalysis (SIMS), nanoindentation
- Fluorine chemistry lab
- Radiochemical labs
- Spent fuel reprocessing and disposal
- MSR/FHR development

Development → Experiments → Testing → Evaluation

- Materials
- Anaerobic corrosion tests
- Geotechnical experiments
The second phase of the SUSEN project will address the following areas:

- Support to operation and maintenance of Gen II and III reactors, in particular concerning inspections, non destructive testing and life extension R&D;

- Support to Gen IV reactors development through material studies at relevant conditions in dedicated loops and including in-pile irradiations;

- Development of a molten salt cooled small modular reactor - in cooperation with US research institutions - as a potential product of the Czech industry;
Promotion of LVR-15 reactor irradiation services, LR-0 reactor physics experiments and associated analytical services;

Exploitation of the potential of our hot cells for material testing of irradiated materials and development of pyrochemical processes;

Use of our LOCA, gamma irradiation and cold crucible facilities, together with an advanced modelling capability, to foster severe accident studies.
In conclusion:

CVŘ is focused to become an excellent pre-commercial research company and, in this context, a valuable cooperation partner for international stakeholders.
THANK YOU FOR YOUR ATTENTION