Status of NEA Nuclear Science activities related to accident tolerant fuels

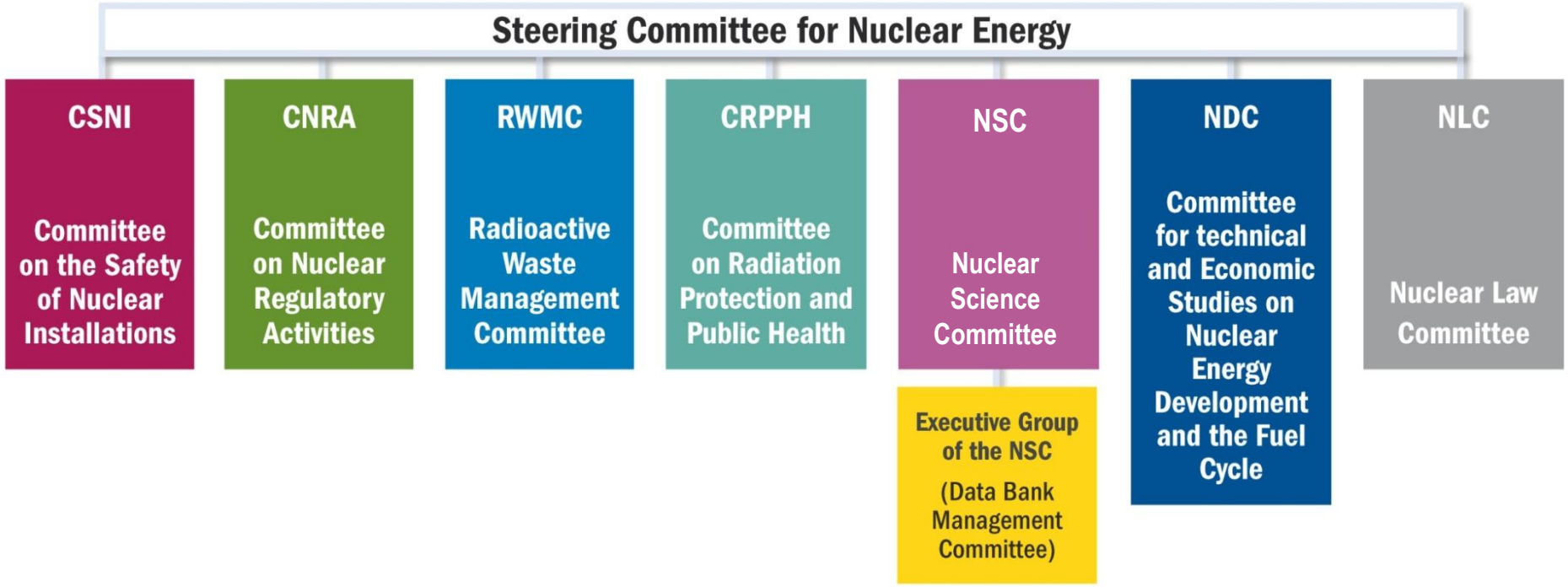
Jim Gulliford, Head of Nuclear Science
OECD-NEA

Outline

- **OECD-NEA Nuclear Science & Data Bank**
  - **Activities related to innovative fuels and fuels performance**

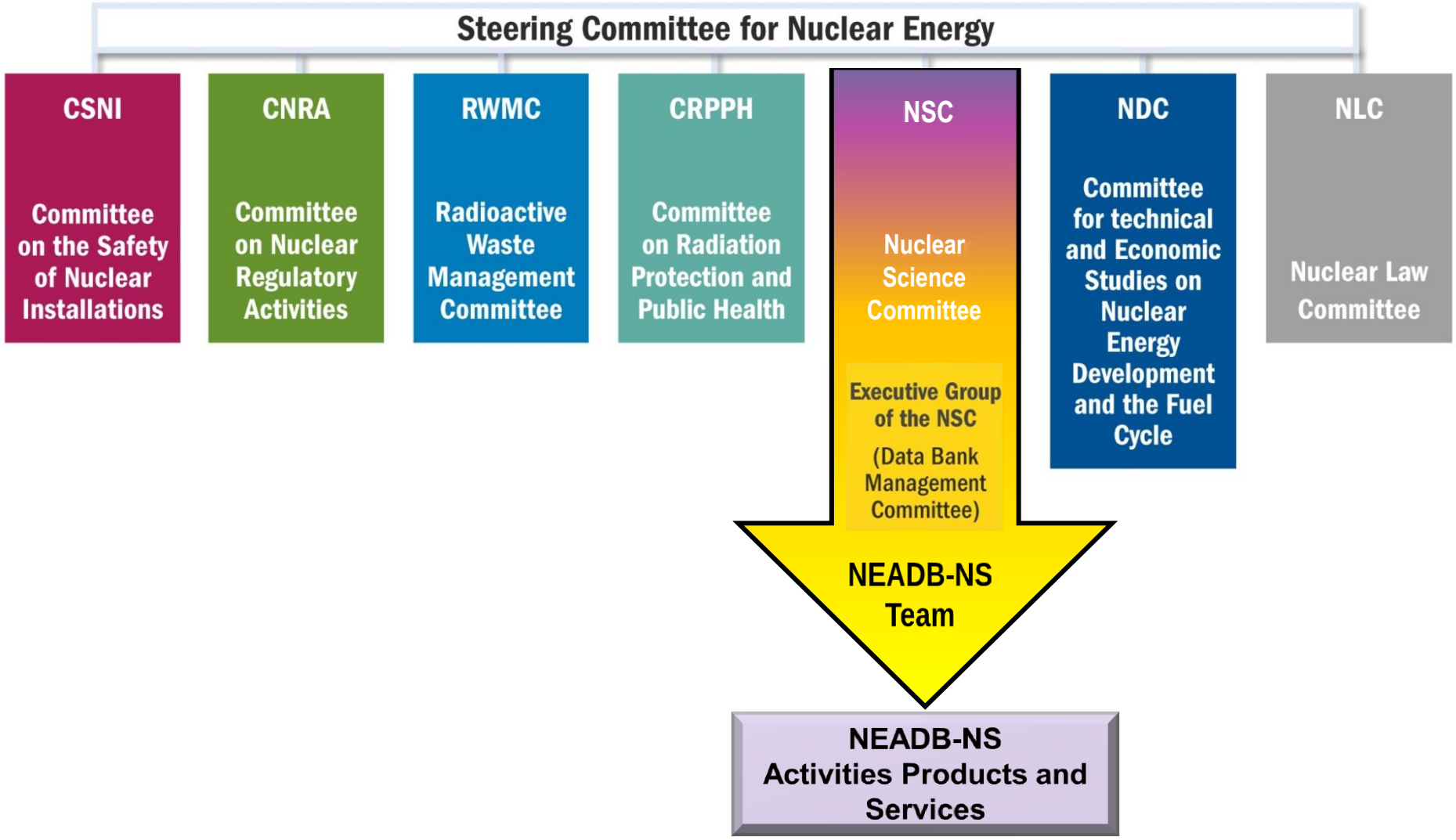
- **Nuclear Science Activity on ATF for LWRs (EGATFL)**
  - **Response to Fukushima**
  - **Nuclear Science Workshops on ATF**
  - **Initiation of Programme of Work under New Expert Group**

NEA Committees



As of 18 September 2012

Nuclear Science-Data Bank Products & Services



Nuclear Science Committee (NSC)

Expert Group on Integral Experiments for Minor Actinide Management

Working Party on International Nuclear Data Evaluation Co-operation (WPEC)

- High Priority Request List for Nuclear Data
- Methods and Issues for the Combined Use of Integral Experiments and Covariance Data
- Co-ordinated Evaluation of ^{239}Pu in the Resonance Region
- Scattering Angular Distribution in the Fast Energy Range
- Evaluation of Experimental Data in the Resolved Resonance Region

Working Party on Scientific Issues of the Fuel Cycle (WPFC)

- Heavy Liquid Metal Technologies
- Fuel Recycling Chemistry
- Advanced Fuel Cycle Scenarios
- Innovative Structural Materials
- Innovative Fuels
- Task Force on Benchmarking of Thermal-hydraulic Loop Models for Lead-alloy-cooled Advanced Nuclear Energy Systems

Working Party on Multi-scale Modelling of Fuels and Structural Materials for Nuclear Systems (WPMM)

- Validation and Benchmarks of Methods
- Multi-scale Modelling Methods
- Structural Materials Modelling
- Multi-scale Modelling of Fuels
- Primary Radiation Damage

Working Party on Nuclear Criticality Safety (WPNCS)

- Advanced Monte Carlo Techniques
- Criticality Safety Benchmarks
- Burn-up Credit
- Criticality Excursions
- Assay Data of Spent Nuclear Fuel
- Uncertainty Analyses for Criticality Safety Assessment

Working Party on Scientific Issues of Reactor Systems (WPRS)

- Reactor Physics and Advanced Nuclear Systems
- Uncertainty Analysis in Modelling
- Reactor Fuel Performance
- Radiation Transport and Shielding

Executive Group of the NSC

(Data Bank Management Committee)

Databases and Scientific Services

The Scientific Co-ordination Group of the Joint Evaluated Fission and Fusion (**JEFF**) Data Project

As of 18 September 2012

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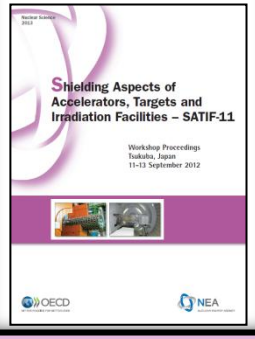
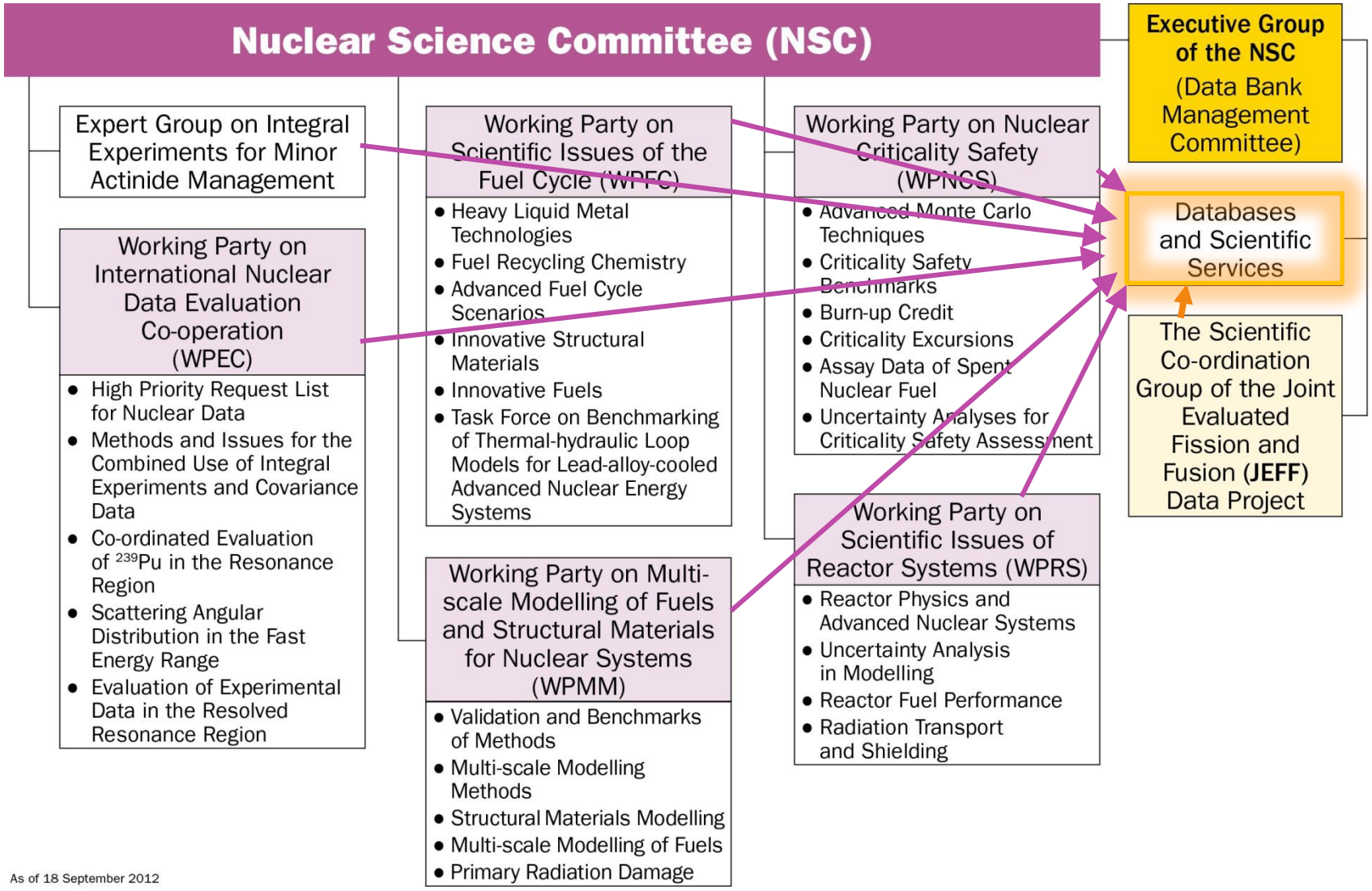
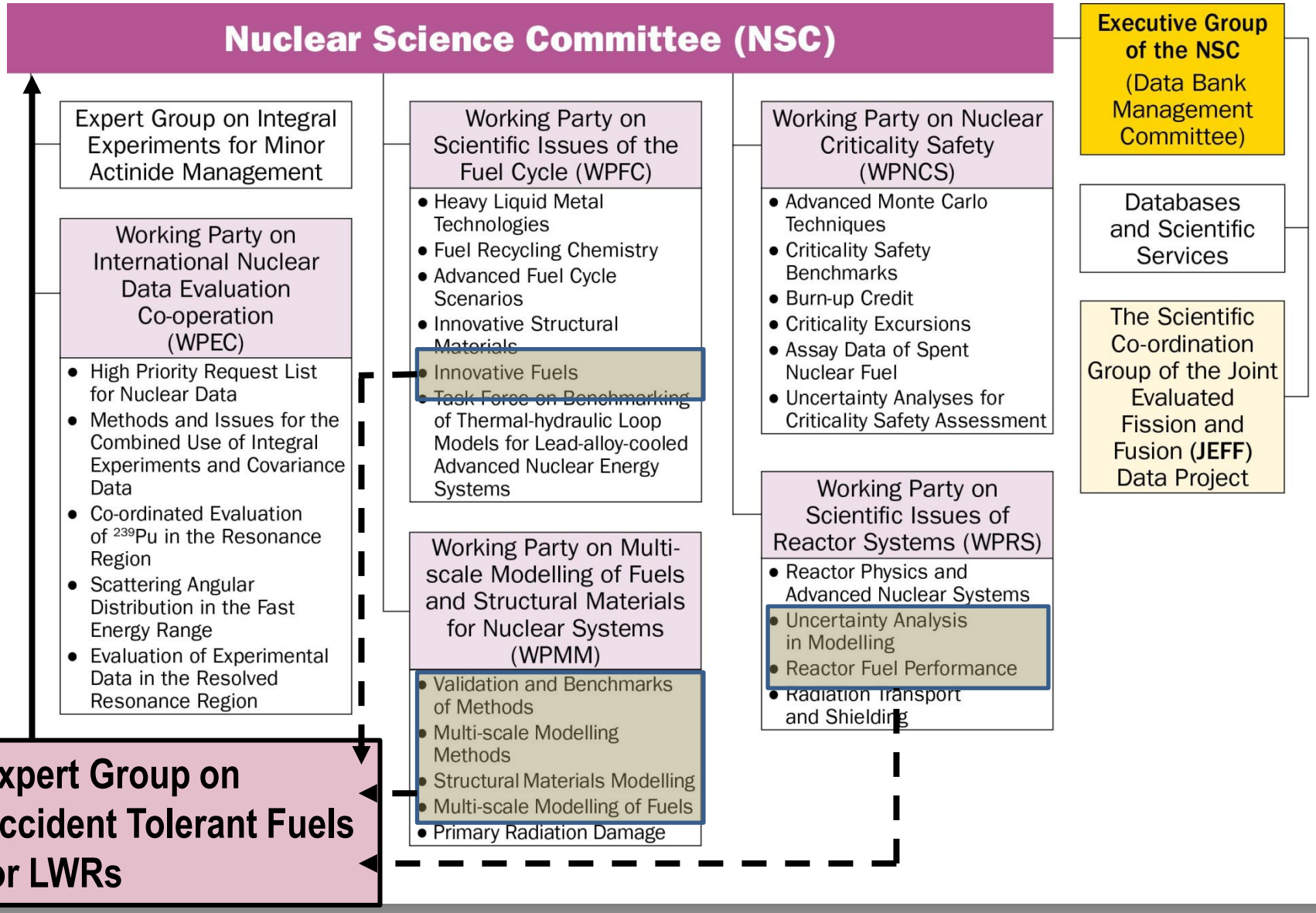
Nuclear Science Publications

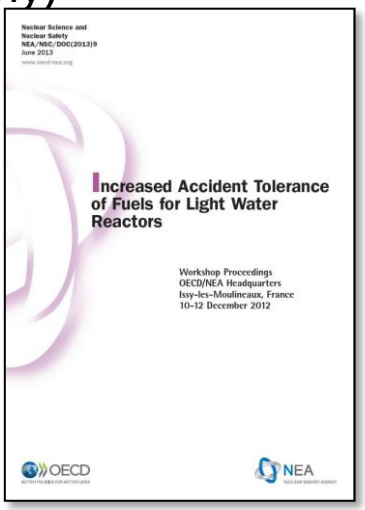






Background to Formation of New NEA EGATFL

- **June 2011 Ministerial Meetings, International Fukushima Forum**
- **June 2011 Nuclear Science Meeting** – NSFF e-forum
- **November 2011 Nuclear Science Bureau**
  - Discussion threads from NSFF reviewed
  - Fukushima identified as topic of in-depth discussion at 2012 NSC meeting
- **June 2012 Nuclear Science Meeting**
  - Proposal for ATF Workshop received from the Working Party on Scientific Issues of the Fuel Cycle (K. Pasamehmetoglu, K. McCarthy)
- **10-12 December 2012: 1st OECD-NEA Workshop on Increased Accident Tolerance of Fuels for LWRs**
- **28-29 October 2013: 2nd OECD-NEA Workshop on Increased Accident Tolerance of Fuels for LWRs**
- **28-29 April 2014: Start-up meeting of EGATFL**
- **23-25 September 2014: 2nd EGATFL meeting**



U.S. DEPARTMENT OF ENERGY
Nuclear Energy

NEA NUCLEAR ENERGY AGENCY

Definition of Accident Tolerant Fuels

Fuels with enhanced accident tolerance are those that, in comparison with the standard UO_2 – Zircaloy system, can **tolerate loss of active cooling** in the core for a **considerably longer time period** (depending on the LWR system and accident scenario) while maintaining or improving the fuel performance during normal operations.

Improved Reaction Kinetics with Steam
- Heat of oxidation
- Oxidation rate

Slower Hydrogen Generation Rate
- Hydrogen bubble
- Hydrogen explosion
- Hydrogen embrittlement of the clad

High temperature during loss of active cooling

Improved Fuel Properties
- Lower operating temperatures
- Clad internal oxidation
- Fuel relocation / dispersion
- Fuel melting

Improved Cladding Properties
- Clad fracture
- Geometric stability
- Thermal shock resistance
- Melting of the cladding

Enhanced Retention of Fission Products
-Gaseous FPs, Solid/liquid FPs

From K. Pasamehmetoglu (INL), Summary of the US National Workshop, OECD-NEA Workshop on ATF, Dec. 2012

Key Elements of PoW for New NEA Expert Group

- **Data and characteristics of candidate materials**, including:
  - Advanced claddings: coated Zr-based alloys, SiC/SiC ceramic composites, advanced steels, refractory metals (e.g. molybdenum), etc.;
  - Advanced Fuels: doped UO_2 for enhanced thermo-mechanical properties, high density fuels such as U-silicide and U-nitride, dispersion fuels with coated particles, etc.;
  - Non-fuel core components such as fuel channels, control rods and blades, and fuel assembly hardware;
- Issues related to the **modelling of the advanced materials** (fuel/cladding behaviour in normal and transient conditions, including DBA and BDBA, etc.);
- A review of **the needs related to an experimental validation** of the most promising materials: available facilities, opportunities of joint experiments (including out-of-pile and in-pile experiments), identification of gaps, etc.
- The **establishment of appropriate metrics** to help prioritise between the ATF candidates;
- The definition and **evaluation of reference scenarios** to evaluate the effectiveness of ATF candidates.

EGATFL Structure

Expert Group on Accident Tolerant Fuels of LWRs (EGATFL)

Information Exchange and Technical Discussions on general issues of ATF

Chair:
K. Pasamehmetoglu (INL)

Task Force 1
Systems Assessment

- Metrics
  - Economics
  - Fuel cycle (SNF, …)
  - Operations
  - DBAs
  - BDBAs
  - …
- TRL definition
- Illustrative Scenario (to feed TF1 and TF2)
- Parametric studies
- System codes

Deliverables

- Definition of illustrative scenarios and first parametric studies
- State-of-the-art report (metrics, system codes)+ Recommendations and priorities

Chair:
S. Bragg-Sitton (INL)

Task Force 2
Cladding/Core Materials

- Properties
- Evaluation under normal operations (incl. fretting)
- Evaluation under illustrative scenario
- PCI
- Testing needs – data gaps (to be linked to RTFDB)
- Modeling needs – modeling gaps
- Experimental infrastructure

Deliverables

- State-of-the-art report + Recommendations and priorities

Chair:
M. Moatti (EDF)

Task Force 3
Fuel Concepts

- Properties
- Evaluation under normal operations (incl. fretting)
- Evaluation under illustrative scenario
- PCI
- Testing needs – data gaps

(to be linked to RTFDB)

- Modeling needs – modeling gaps
- Recommendations on priorities

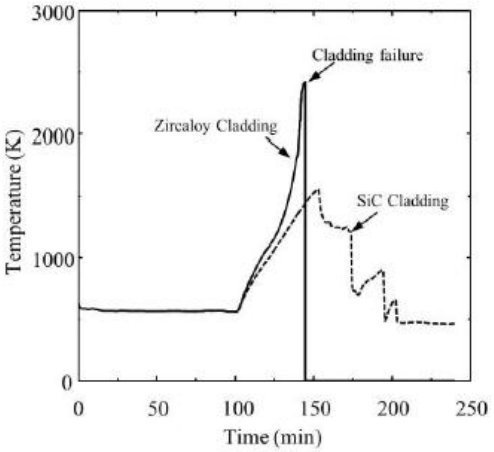
Deliverables

- State-of-the-art report + Recommendations and priorities

Chair:
M. Kurata (JAEA)

ATF candidates: Cladding

- Advanced steels (e.g. FeCrAl)
- Refractory metals (e.g. Mo)
- Ceramic cladding (SiC)
- Innovative alloys with dopants
- Zircaloy with coating or sleeve
  - SiC CMC
  - MAX-phase ceramics
  - Other



Comparison of MELCOR predicted cladding oxidation heating produced during a TMI-2 accident sequence.

Each concept has some pros and cons across the spectrum of operating and transient conditions of interest. A systematic analytical and experimental evaluation is being performed during the feasibility studies.

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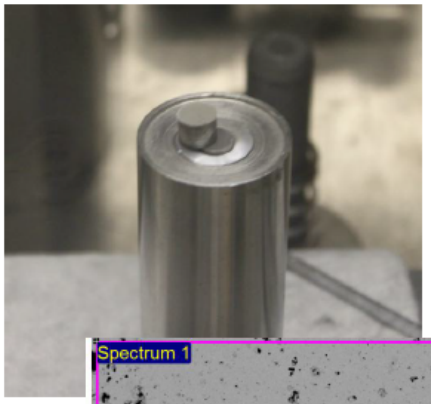
From S. Bragg-Sitton (INL), OECD-NEA Start-up Meeting of EGATFL, Apr. 2013

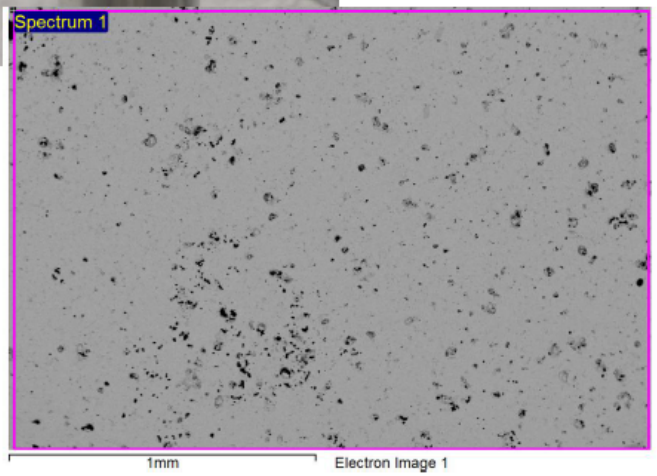
ATF candidates: Fuel

- **Higher density fuels (metal, nitride, silicide)**
  - Higher thermal conductivity
  - Higher fissile density to compensate for neutronic inefficiency of some new cladding concepts without increasing enrichment limits
- **Oxide fuels with additives**
  - Higher thermal conductivity
  - Fission product gettering
- **Microencapsulated fuels**
  - Particle fuel dispersed in a ceramic or metallic matrix



Uranium Silicide Fabrication

Highest achieved density: 94.6% theoretical (11.5 g/cc)



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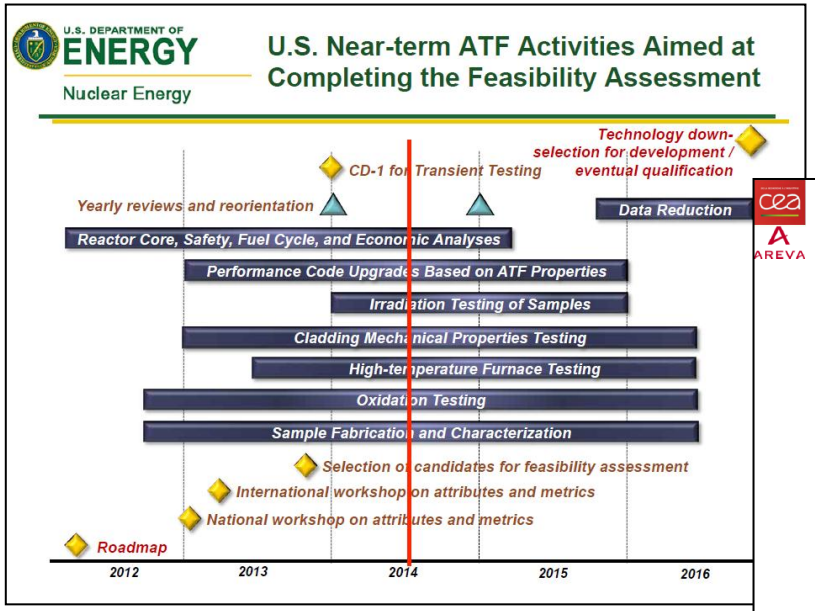
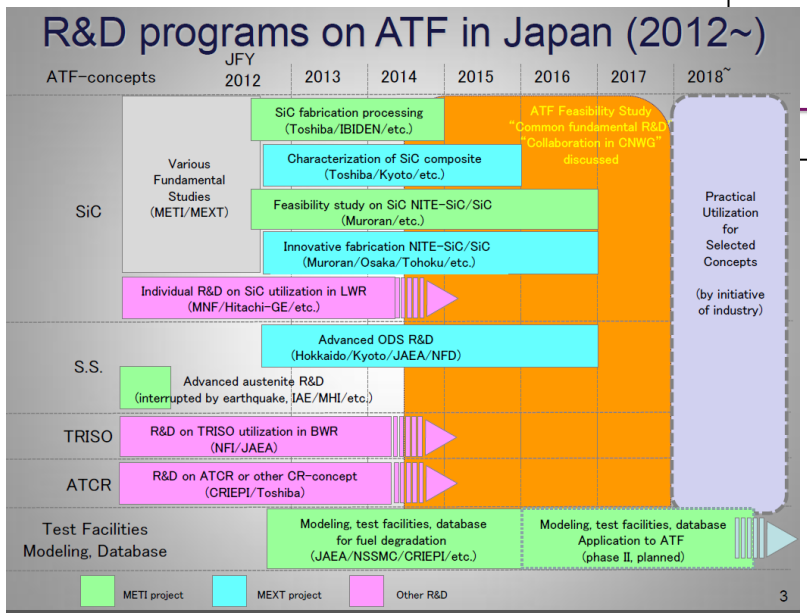
From S. Bragg-Sitton (INL), OECD-NEA Start-up Meeting of EGATFL, Apr. 2013

Examples of Timelines for ATF development





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SYNERGIES WITH OTHER INTL PROGRAMS

OECD-NEA Halden Reactor Project (WGFS)

- **Proposal for irradiation testing of Cr-coated- Zy-4/UO2 – fuel rodlets (White paper submitted)**
- **Goals**
  - Step 1
    - Direct evaluation of under representative PWR conditions
    - Stability of the protective effect of coating
      - In environment
      - In environment + local deformation (special design for early contact)
    - Conditioning irradiated rodlet(s) for LOCA test in a second step
  - Step 2
    - LOCA test – Direct benefit evaluation
- **Timing**
  - 15 - 20 cm length clads may be short term delivered now
  - 50 - 60 cm clads could be fabricated end 2014 / early 2015
  - Discussion on detailed program and PIE expected around mid-2014

NUGENIA Technical Area 5 :

-several proposals to be coordinated around ATF cross evaluation goals and basic data acquisition (Falstaff, Forclad, Ramat, …) → Call H2020 in 2014/9
- need of harmonization with other ATF initiatives

EGATFL: 30 organisations from 13 member countries + PRC

Country	Organisation
Belgium	SCK-CEN
P.R. of China	CGN
Czech Rep.	ALVEL
France	AREVA
	CEA
	EDF
	IRSN
Germany	KIT
Japan	CRIEPI
	JAEA
	Kyoto University
	Muroran Inst. Techn.
	NFD
	Toshiba

Country	Organisation
Rep. of Korea	KAERI
Norway	OECD-Halden
Russian Federation	Kurchatov Institute
	NITI
Switzerland	PSI
Sweden	Westinghouse
USA	AREVA
	EPRI
	GE
	INL
	Univ. Illinois
	Univ. Florida
	MIT
	ORNL
UK	NNL

P.R. of China	CGN

International org.	IAEA

- Next EGATF Meeting will be 3-5 March 2015 at NEA Offices

- Thank you for your attention….