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Nuclear Energy Cooperation with Japan Following the Fukushima Daiichi Accident

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Outline

- Nuclear Energy in Japan
- Overview of Fukushima Accident and Response
- Lessons Learned \ Implications to U.S. Nuclear Fleet
- DOE Nuclear Energy Research Program
- R&D Cooperation with Japan
- Conclusions

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Nuclear Energy in Japan

- **Japan has a robust civil nuclear energy industry**
  - Third largest nuclear generating capacity behind the U.S. and France
  - Pre-Fukushima, 30% of electricity generation was from nuclear power
- **Japan is a major player in the U.S. nuclear power sector and world market**
  - General Electric\Hitachi
  - Toshiba\Westinghouse
  - Mitsubishi Heavy Industries
- **Japan has mature programs in advanced reactor and fuel cycle research and development**

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Japan's Evolving Nuclear Policy

- **Prior to the accident the GOJ was planning on expanding nuclear power generation from ~30% to up to 50% of electricity generation**
- **Following the accident, the Democratic Party of Japan (DPJ) advocated for a complete restructuring of Japan's energy policy**
  - Adopted a party platform calling for a complete phase out nuclear power in the 2030s
- **Elections in Dec 2012 secured a strong majority in the House of Representatives for the Liberal Democratic Party (LDP)**
  - Prime Minister Noda was replaced by Prime Minister Abe
- **Elections in July 2013 to the Upper House of the Diet may influence future nuclear energy policy in Japan**

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Fukushima Daiichi Reactors

- **6 Boiling Water Reactors (GE Type 3, 4, 5 – Mark I, II containments)**
  - Units 1, 2, 3 operating – Units 4, 5, 6 shutdown for maintenance
- **Magnitude 9.0 earthquake, followed by several tsunami waves**
  - Units 1, 2, 3 reactors automatically shut down and EDGs started as designed

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Immediate U.S. Response

U.S.NRC

- Activated its Emergency Operations Center
- Immediately deployed personnel to the U.S. Embassy in Japan to support the Reactor Safety Team
- Provided expert advice to U.S. Ambassador and Government of Japan
- Set up and coordinated consortium call that involved NRC, INPO, DOE, and Naval Reactors

INPO

- Organized nuclear industry technical response to assist TEPCO

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- Activated its Emergency Operations Center focused on monitoring radiation release and impact on U.S. citizens (both in Japan & U.S.)
- Deployed Airborne Monitoring System aircraft and sensors
- Provided additional DOE Embassy reps to the two already assigned to the U.S. Embassy
- Deployed national laboratory reps from INL, PNNL and Sandia to provide technical assistance
- Stood up Science Council supported by DOE staff and labs

- Provided equipment and capabilities to assist Japan

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DOE Analysis for Initial and Stabilization Phase

Collection of daily status data and events

Isotopic analysis of releases

H2 production and explosions in reactor buildings

N2 inerting options and processes

Gas inventory calculations

Potential for further H2 production and explosions

Structural analysis of RPV after pressure spikes

Core damage and fuel condition

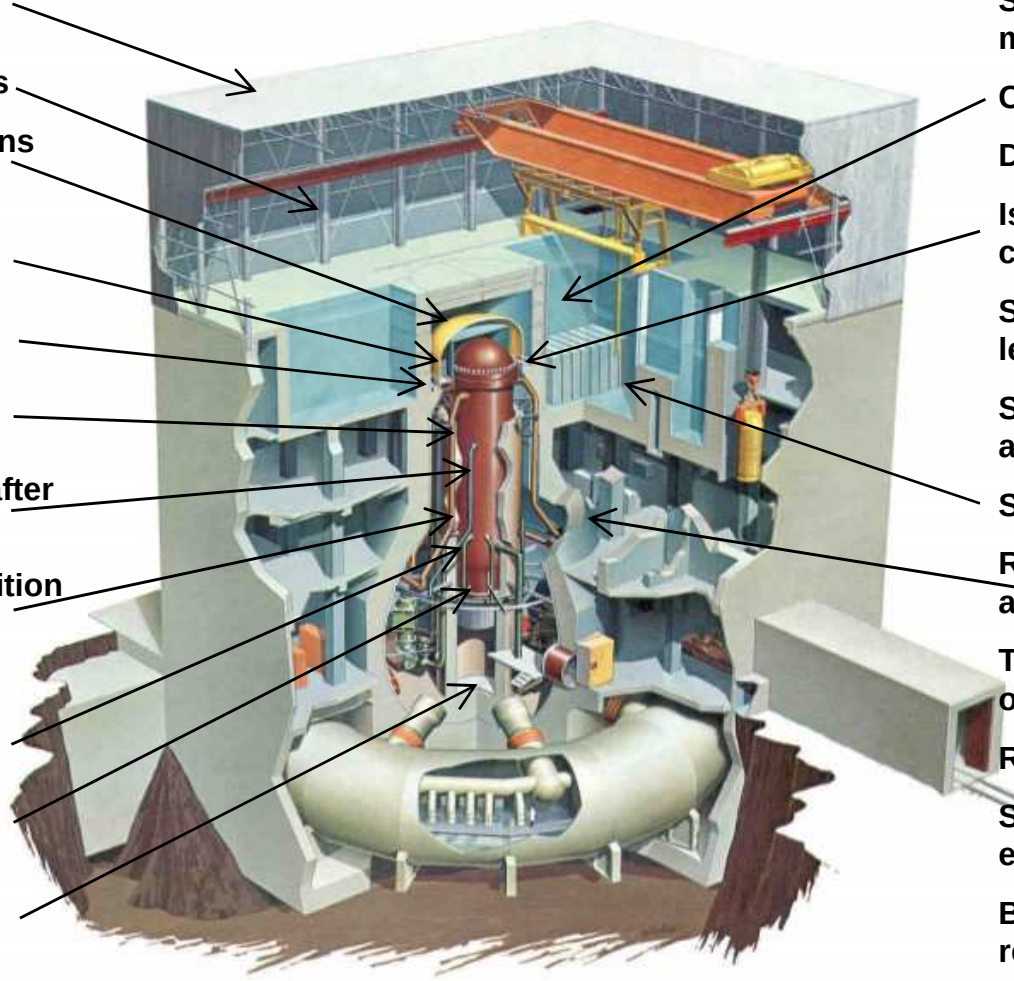
Sensor data analysis

Water level calculations

Corrosion in sea water solutions

Drywell filling options and water level tracking

Stabilization criteria



Severe accident analysis and management

Criticality determinations

Decay heat calculations

Isotope and radionuclide calculations and releases

Spent Fuel Pool (SFP) water level analysis

SFP hydrogen production and analysis

SFP modeling

Reactor building and SFP dose assessments

Thermal analysis for SFP fill options

Robotics tools for stabilization

Shielding advice for on-site equipment

Bioaccumulation for water releases

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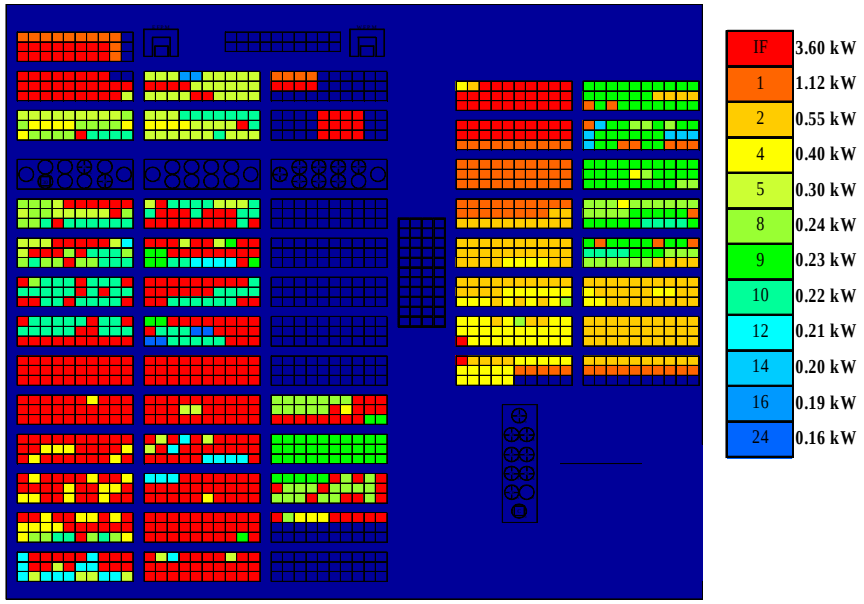
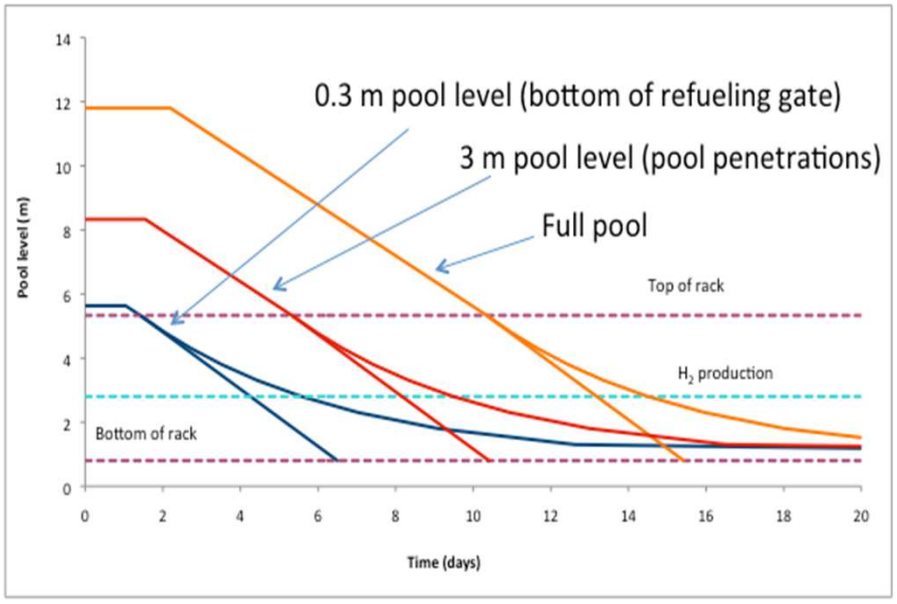
Thermal analysis of Unit 4 Spent Fuel Pool heat up and boil off

- Models of spent fuel pools developed to predict pool boil off time and to understand hydrogen production
- Used to perform analysis of pool leakage scenarios
- Calculations based on several codes and models to provide range in turn-around time and fidelity

UNIT 4 SFP HEAT GENERATION RATE DISTRIBUTION



POOL LEVEL FOR VARIOUS SCENARIOS FOR UNIT 4



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Response to Fukushima – NRC and Industry

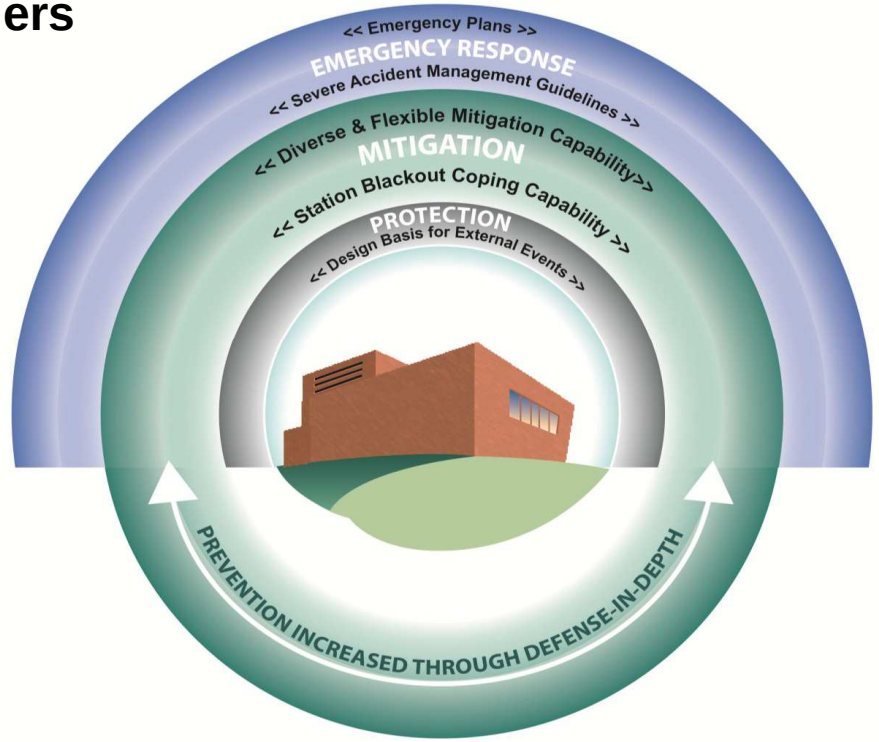
U.S. Nuclear Regulatory Commission (NRC)

- Near-Term Task Force (NTTF) recommendations (July 2011)
- Recommendations prioritized into 3 Tiers (SECY-11-0137, October 3, 2011)
- Three orders issued March 2012

U.S. plants are safe…no imminent risks from continued operation and licensing activities ..similar events in the U.S. very unlikely.

U.S. Nuclear Industry – "FLEX" Strategy

- Establishing diverse and flexible mitigation capabilities
- Builds on post-9/11 enhancements
- Reliable backup electrical power and cooling capability in extreme events



FLEX Strategy

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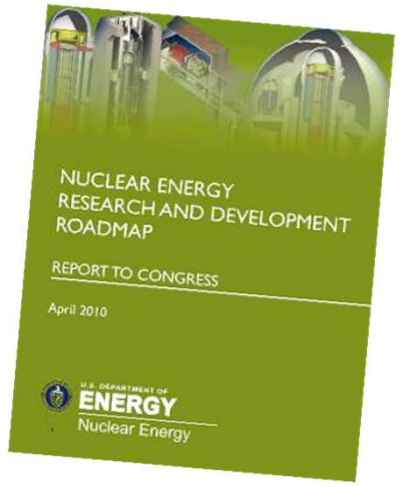
DOE Office of Nuclear Energy Research Activities

- **DOE-NE initiated or reoriented a number research activities in view of the Fukushima Daiichi accident**
  - Joint research activities with the NRC
    - MELCOR severe accident computer analysis
    - Testing of nuclear plant battery systems
  - University led research activities
    - NEUP R&D awards
    - NEUP Integrated Research Projects
  - DOE-NE R&D program activities
    - Accident Tolerant Fuel
    - Accident Tolerant Instruments and Sensors



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Joint DOE – NRC Activities

- **Testing program to better understand the performance characteristics of nuclear plant emergency battery systems during severe accident conditions**
  - extended station blackout
- **MELCOR Severe Accident Study**
  - collect, verify, and document data on the accidents
  - reconstruct the accidents and their progression using MELCOR
  - validate the models and analyses
  - suggest potential future data needs
- **MELCOR study results encouraging in terms of capturing essential accident signatures/trends**
  - although some uncertainties remain

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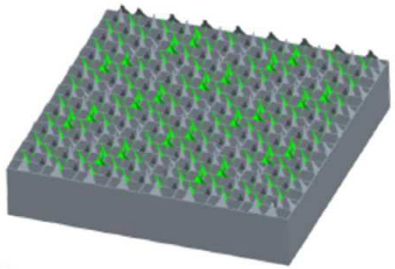
University Led Integrated Research Projects (IRP): Accident Tolerant Fuels

Engineered Zircaloy Cladding Modifications for Improved Accident Tolerance of LWR Nuclear Fuel



Lead: University of Illinois, Urbana Champaign

Collaborators: University of Florida, University of Michigan, University of Manchester, ATI, INL

Budget: $3.5 M

Fabricate and evaluate modified Zircaloy LWR cladding under normal BWR/PWR operation and off-normal events using two pathways:

- modification of the cladding surface by the application of a coating layer
- modification of the bulk cladding composition to promote precipitation of minor phase(s) during fabrication

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University Led Integrated Research Projects (IRP): Accident Tolerant Fuels

Advanced Accident Tolerant Ceramic Coatings for Zr-Alloy Cladding

Lead: University of Tennessee

Collaborators: Pennsylvania State University, University of Colorado-Boulder, University of Michigan, several Great Britain Univs, ANSTO, Westinghouse, LANL

Budget: $3.5 M

Develop an advanced durable ceramic coating for Zr-alloy cladding that exhibits demonstrably improved performance compared to conventional Zr-alloy clad

- characterize the structural and physical properties of the coated clad samples (especially corrosion) under simulated normal and transient conditions
- assess the effects of such coatings on fuel performance, reactor neutronics, and economics

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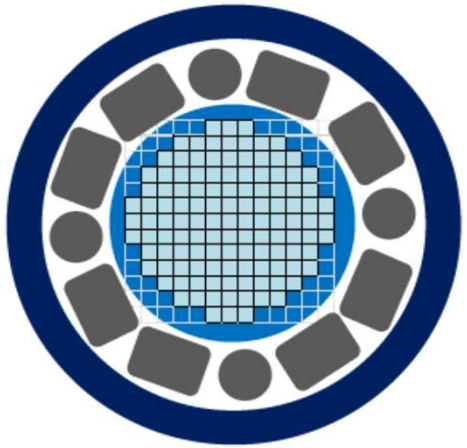
Integrated Research Project: Inherently Safe Reactors

Integral Inherently Safe Light Water Reactor

Lead: Georgia Institute of Technology

Collaborators: University of Michigan, Virginia Tech, University of Tennessee, University of Idaho, Morehouse College, Westinghouse, Southern Nuclear, INL Polytechnic University of Milan, University of Cambridge

Budget: $6.0 M



Large (~1,000 MWe) LWR with inherent safety features. High power density\ compact core design using a non-oxide fuel form

- novel steam generating system is based on very compact printed circuit heat exchangers
- compact design\small plant footprint reduces capital cost and facilitates seismic isolation

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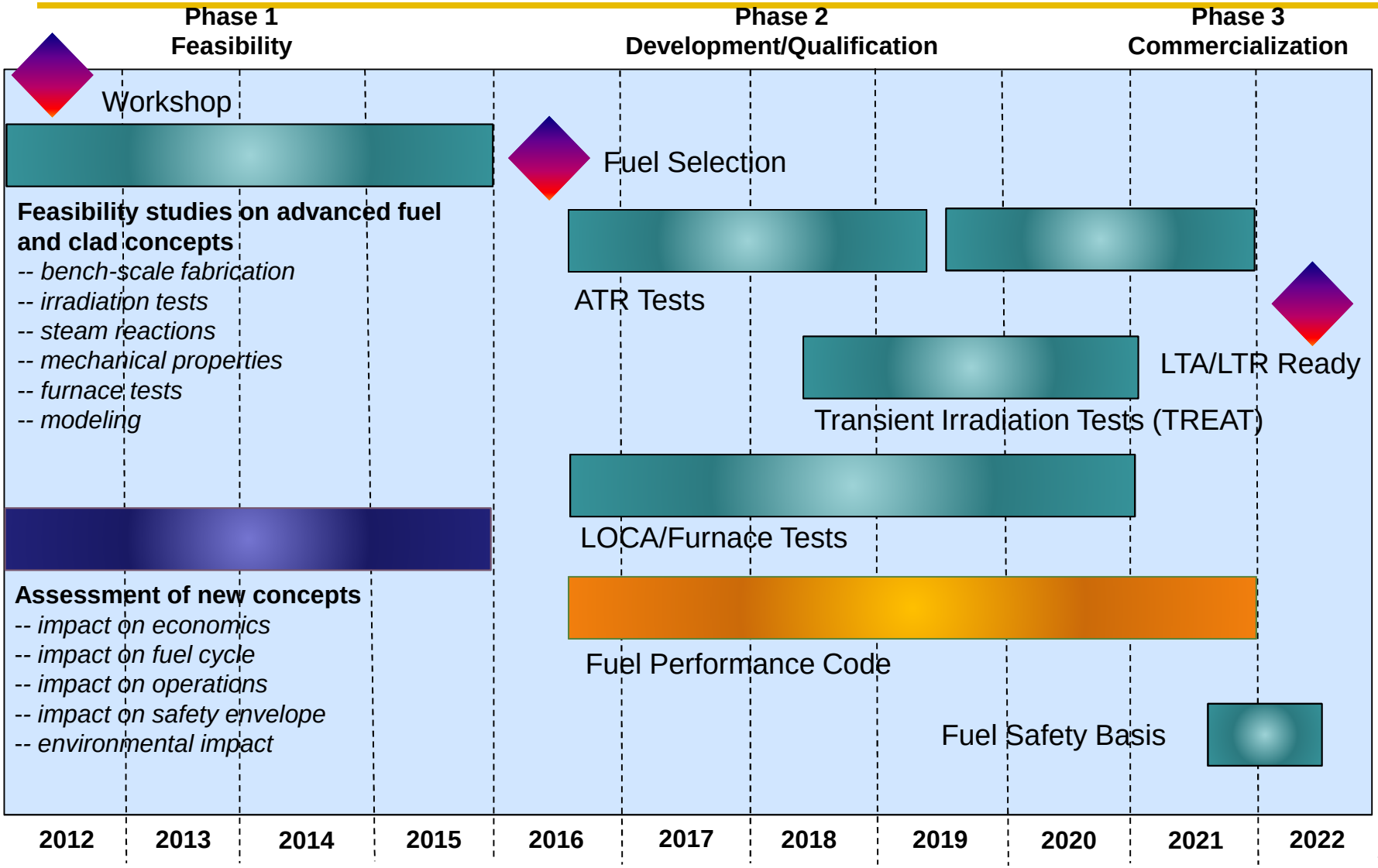
RD&D Strategy For Enhanced Accident Tolerant Fuels



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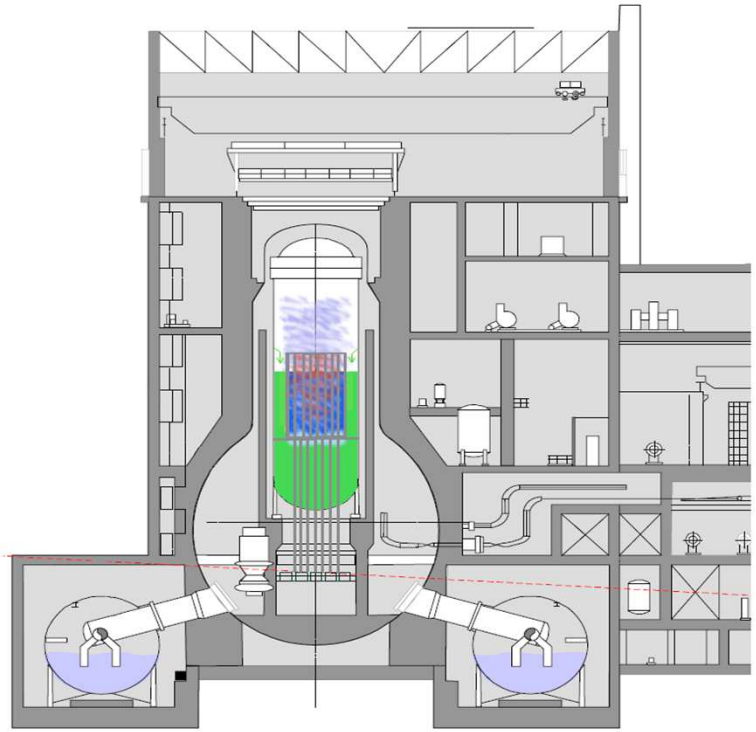
International Cooperation

OECD/NEA Fukushima Benchmarking Project

- Recently initiated a Fukushima Daiichi analysis and benchmarking project that DOE and NRC support
- Results of this effort could guide defueling of Fukushima Daiichi plant
- OECD/NEA effort is expected to:
  - Improve understanding of accident progression
  - Enable comparison and improvement of various models and their methodology
  - Assist in decommissioning planning by evaluating current internal status, including distribution of fuel debris
- DOE will work with Japan and the international community to develop a plan for data collection during defueling



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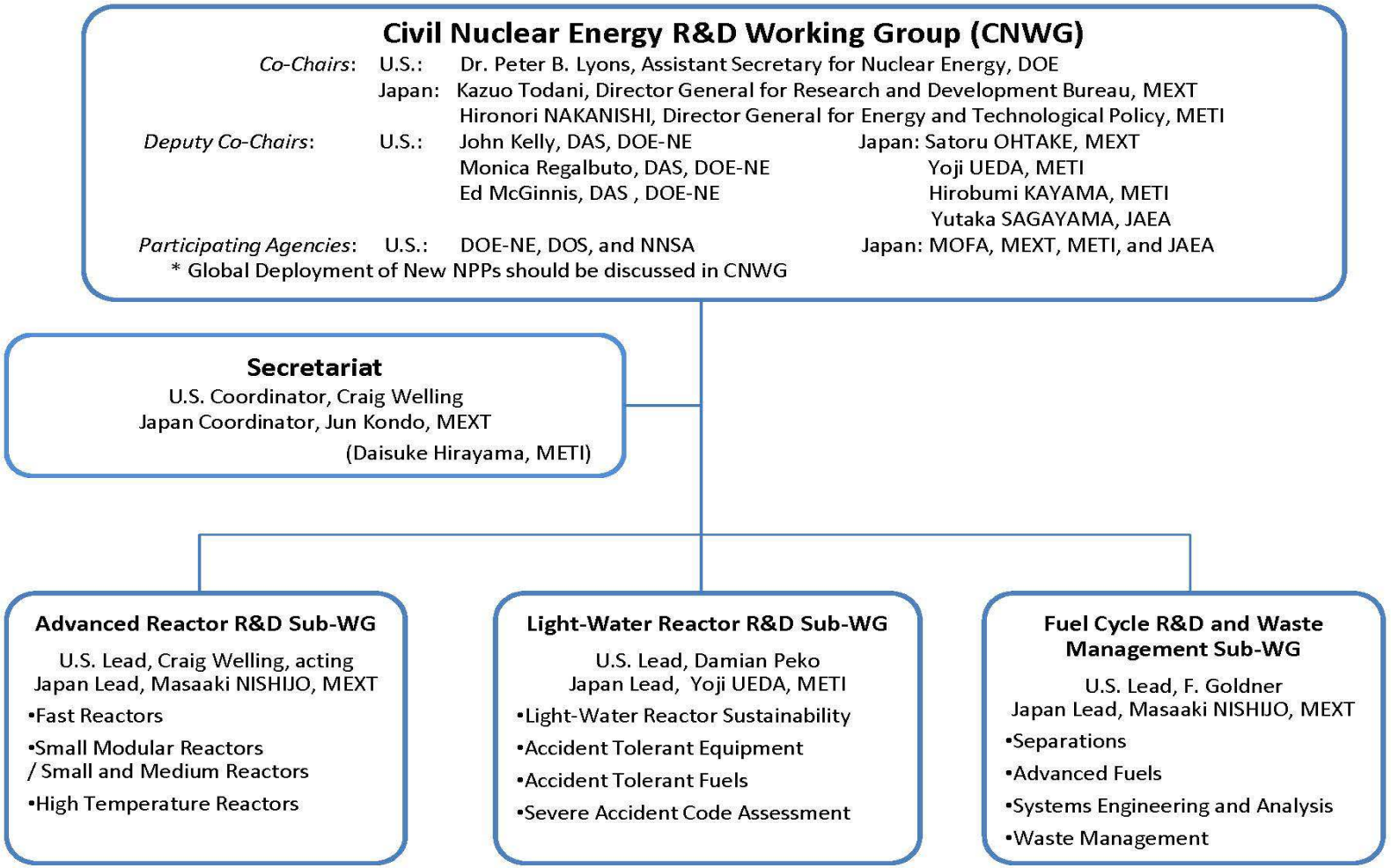
Civil Nuclear Energy R&D Working Group

An element of US-Japan Bilateral Commission on Civil Nuclear Cooperation

- 3 sub-working groups include advanced reactor, light water reactor and fuel cycle R&D
- Builds upon the previous U.S.-Japan Joint Nuclear Energy Action Plan (JNEAP)
- Expands JNEAP activities to include:
  - light water reactor sustainability
  - accident tolerant fuel and equipment
  - severe accident code assessment
- Legal structure for cooperation being developed
  - Gov't to Gov't agreement Mar 2012
  - DOE & MEXT Implementing Arrangement Jan 2013
  - Additional IAs with METI and NRA pending


Civil Nuclear Energy R&D Working Group (CNWG)
Co-Chairs: U.S.: Dr. Peter B. Lyons, Assistant Secretary for Nuclear Energy, DOE
Japan: Kazuo Todani, Director General for Research and Development Bureau, MEXT
Hironori NAKANISHI, Director General for Energy and Technological Policy, METI
Deputy Co-Chairs: U.S.: John Kelly, DAS, DOE-NE
Monica Regalbuto, DAS, DOE-NE
Ed McGinnis, DAS , DOE-NE
Japan: Satoru OHTAKE, MEXT
Yoji UEDA, METI
Hirobumi KAYAMA, METI
Yutaka SAGAYAMA, JAEA
Participating Agencies: U.S.: DOE-NE, DOS, and NNSA
Japan: MOFA, MEXT, METI, and JAEA
* Global Deployment of New NPPs should be discussed in CNWG
Secretariat
U.S. Coordinator, Craig Welling
Japan Coordinator, Jun Kondo, MEXT
(Daisuke Hirayama, METI)
Advanced Reactor R&D Sub-WG
U.S. Lead, Craig Welling, acting
Japan Lead, Masaaki NISHIJO, MEXT
•Fast Reactors
•Small Modular Reactors / Small and Medium Reactors
•High Temperature Reactors
Light-Water Reactor R&D Sub-WG
U.S. Lead, Damian Peko
Japan Lead, Yoji UEDA, METI
•Light-Water Reactor Sustainability
•Accident Tolerant Equipment
•Accident Tolerant Fuels
•Severe Accident Code Assessment
Fuel Cycle R&D and Waste Management Sub-WG
U.S. Lead, F. Goldner
Japan Lead, Masaaki NISHIJO, MEXT
•Separations
•Advanced Fuels
•Systems Engineering and Analysis
•Waste Management

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Conclusions

- **Japan is a key player in the U.S. and global nuclear power industry**
- **U.S. nuclear power plants are safe**
  - NRC and plant operators are working hard to continue the exemplary safety record
  - proactively applying lessons learned from Fukushima
- **DOE is working with the NRC, industry, academia and international partners**
  - to develop even safer nuclear plants
  - enhance the safety and long-term sustainability of the existing fleet
- **The U.S. and Japan have a long history of beneficial cooperation in civilian nuclear energy R&D**
  - DOE will continue to partner with and actively support Japan
  - Bilateral Commission will facilitate cooperative efforts in nuclear energy, safety, security, nonproliferation and environmental management