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NRC's Accident Tolerant Fuel Project Plan and Regulatory Perspectives for Storage and Transportation

US Nuclear Waste Technical Review Board [illegible]

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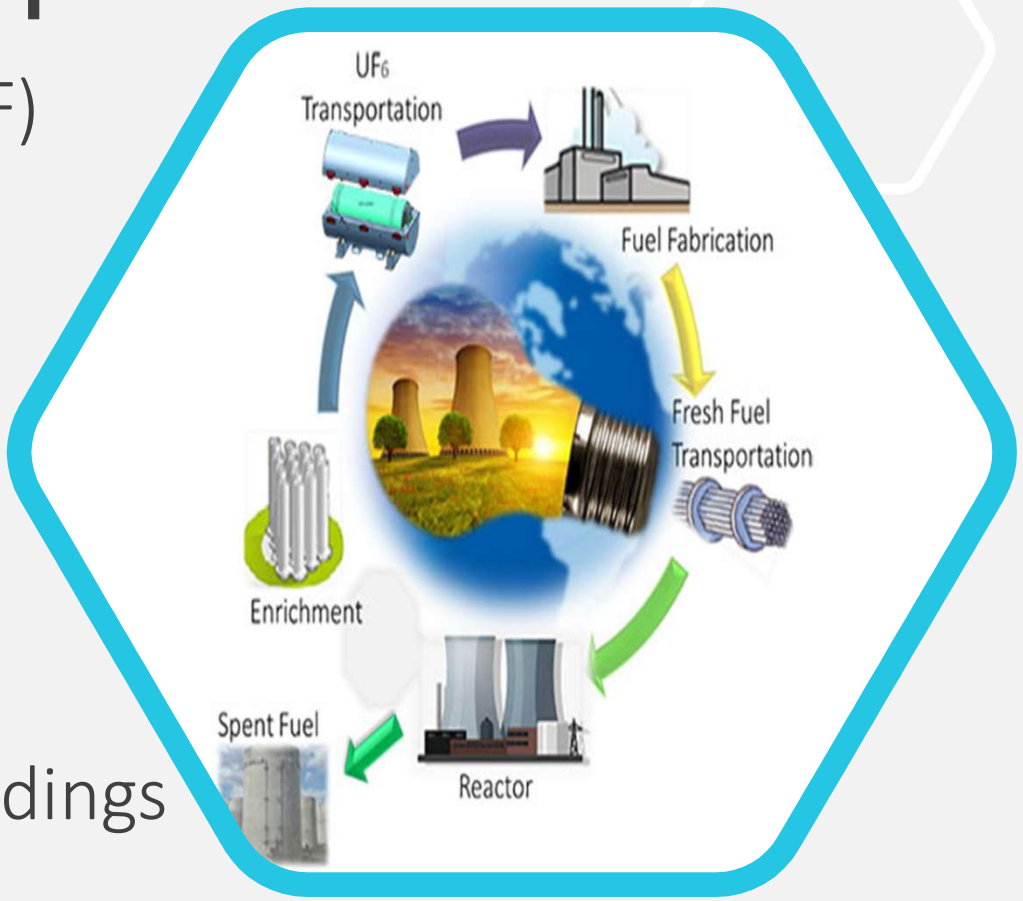
NRC's Accident Tolerant Fuel Project Plan

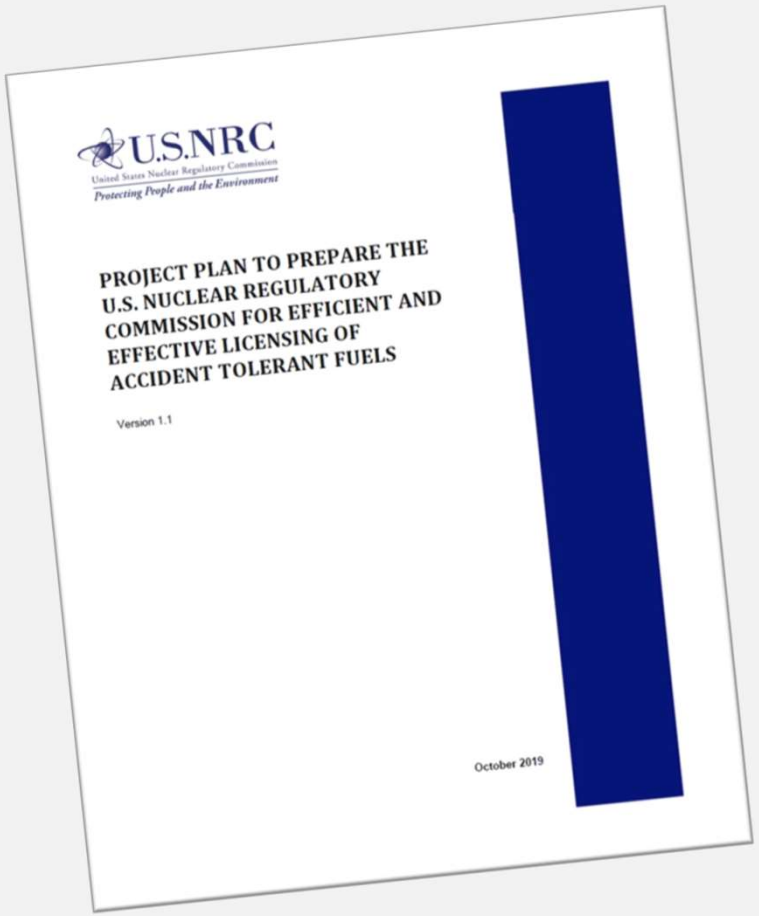
Marilyn Diaz
Project Manager

Topics

- Accident Tolerant Fuel (ATF) concepts
- ATF Project Plan
- Project Plan Revision
- Fuel Cycle, Transportation, and Storage Regulatory Framework
- Research Activities and Findings
- Closing Remarks



ATF Project Plan

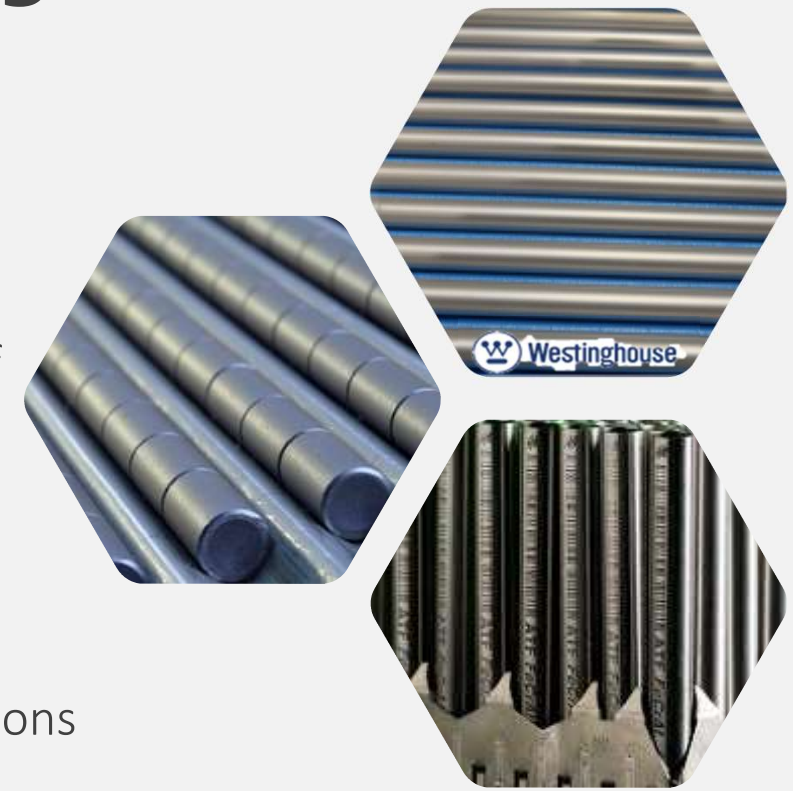


ADAMS Accession No. ML19301B166

- Project plan facilitates the efficient and effective licensing of ATF
- Project plan outlines the activities to prepare NRC for licensing ATF
- Project plan covers complete (front-end to back-end) fuel cycle
- Active stakeholder engagement to keep up with the latest information

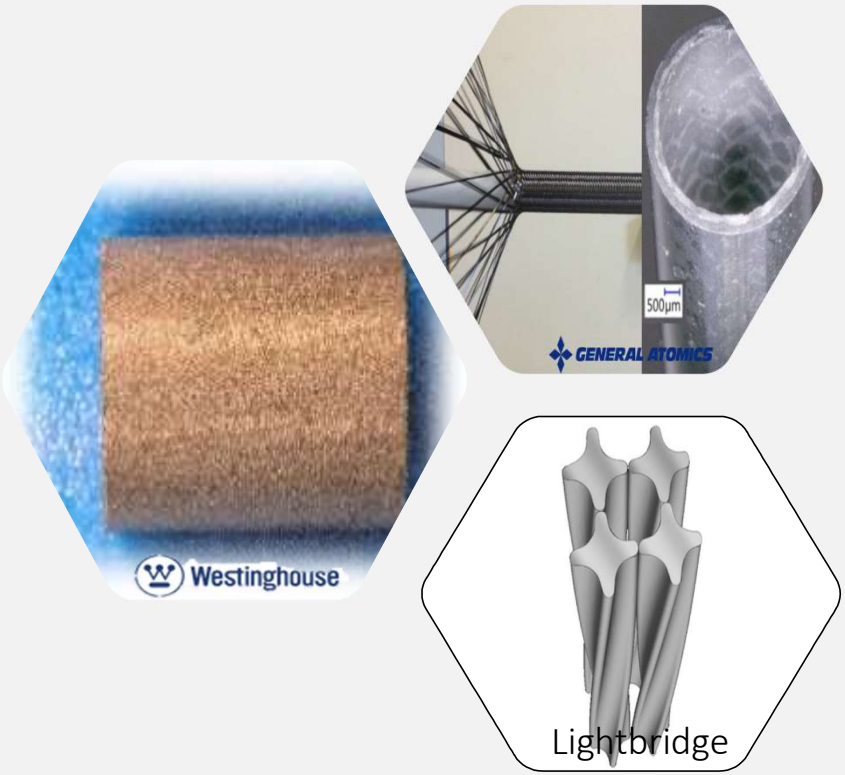
Near-Term ATF Technologies

- Chromium-coated Cladding
  - Multiple vendors
  - Reduce corrosion and metal-water reaction
  - Completed phenomena Identification and Ranking Table (PIRT) report and Interim Staff Guidance
- Doped Pellets
  - Multiple vendors
  - Reduce pellet clad interaction
  - Approved for boiling water reactors applications
- Steel Cladding
  - Iron-Chromium-Aluminum based alloy fuel cladding (FeCrAl)



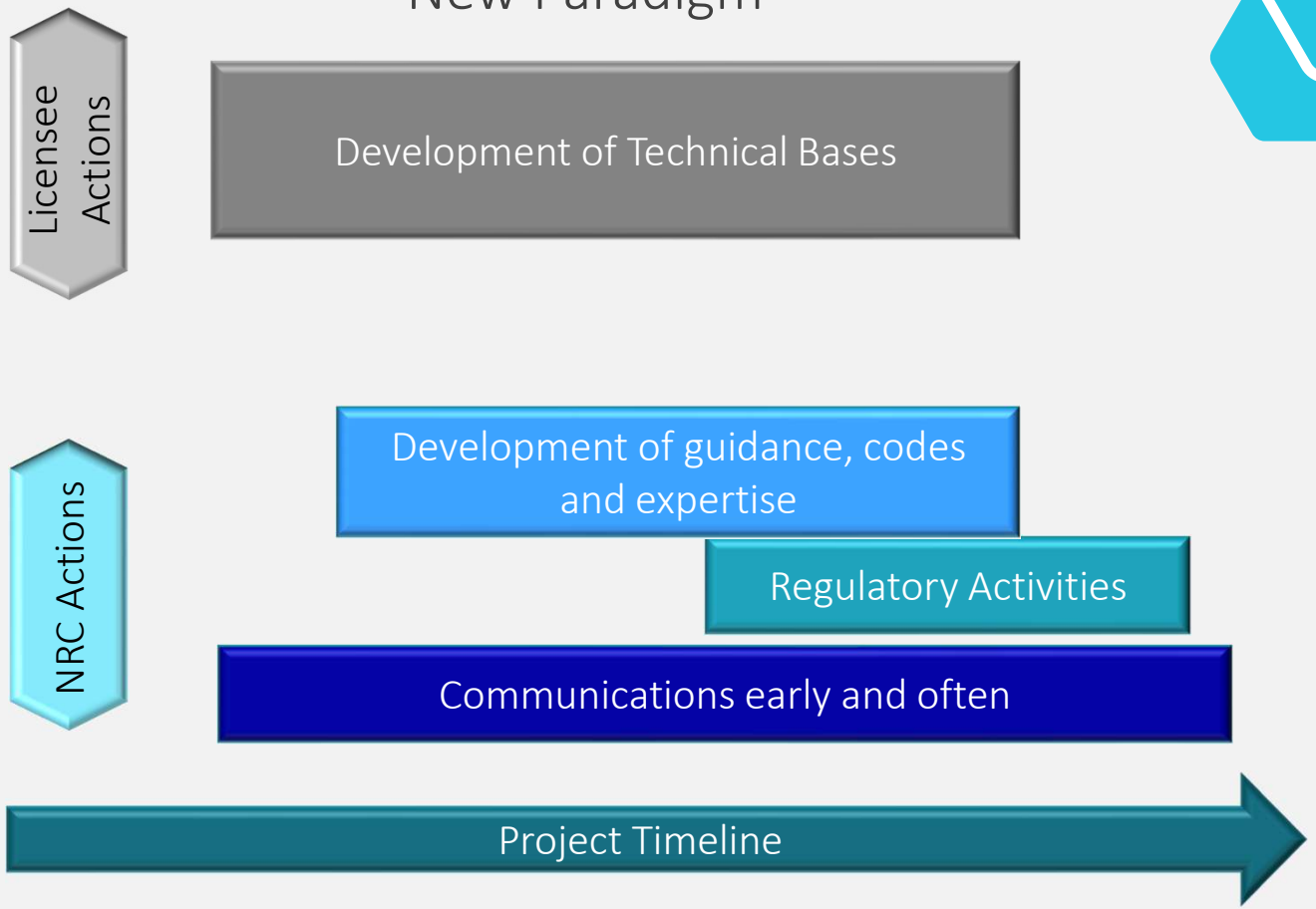
Long-Term ATF Technologies

- Silicon carbide cladding
  - Multiple Vendors
- Uranium nitride pellets
  - Higher fuel density
- Metallic fuel
  - Fuel thermal conductivity compared to ceramics.

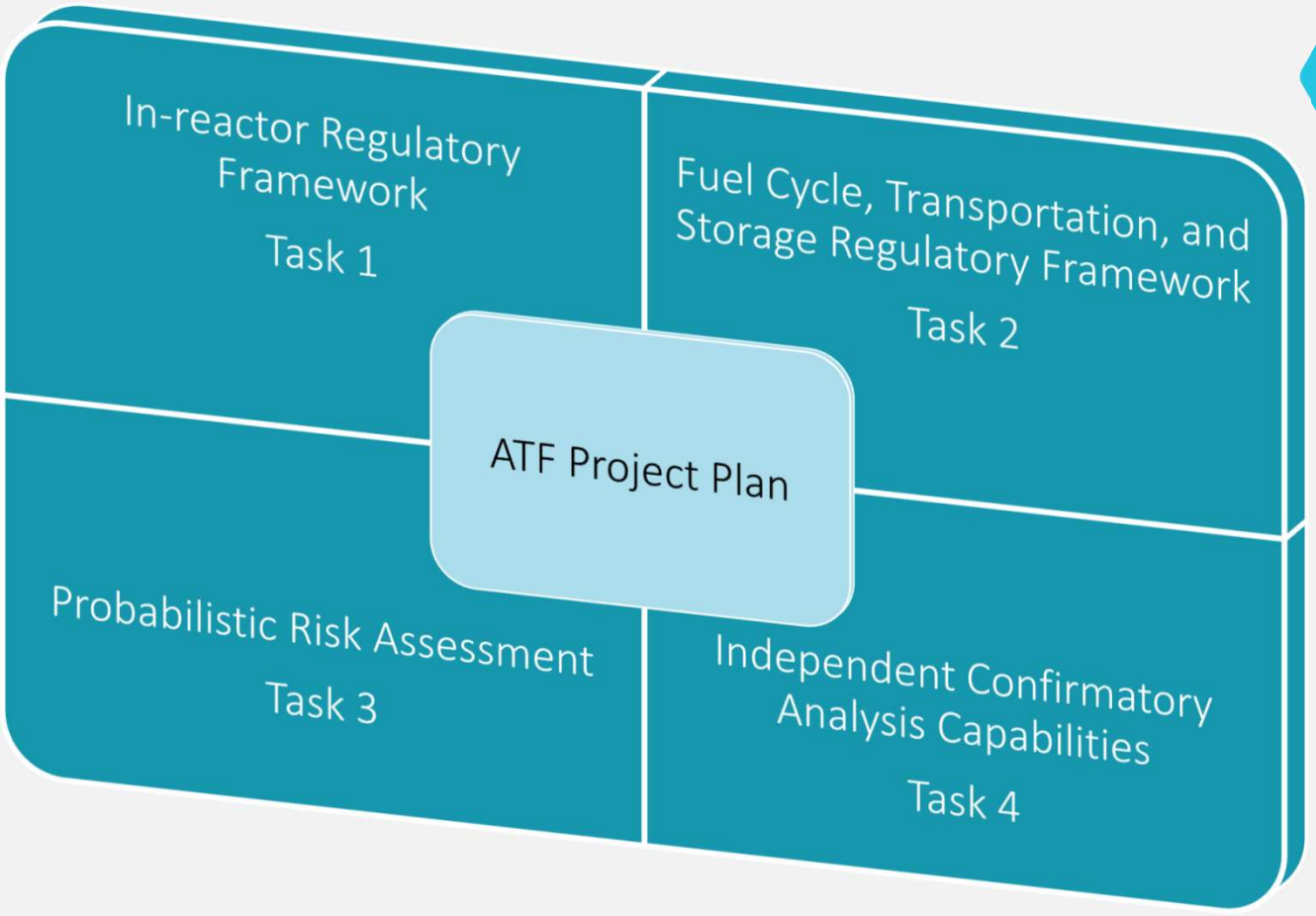


The ATF Project Plan

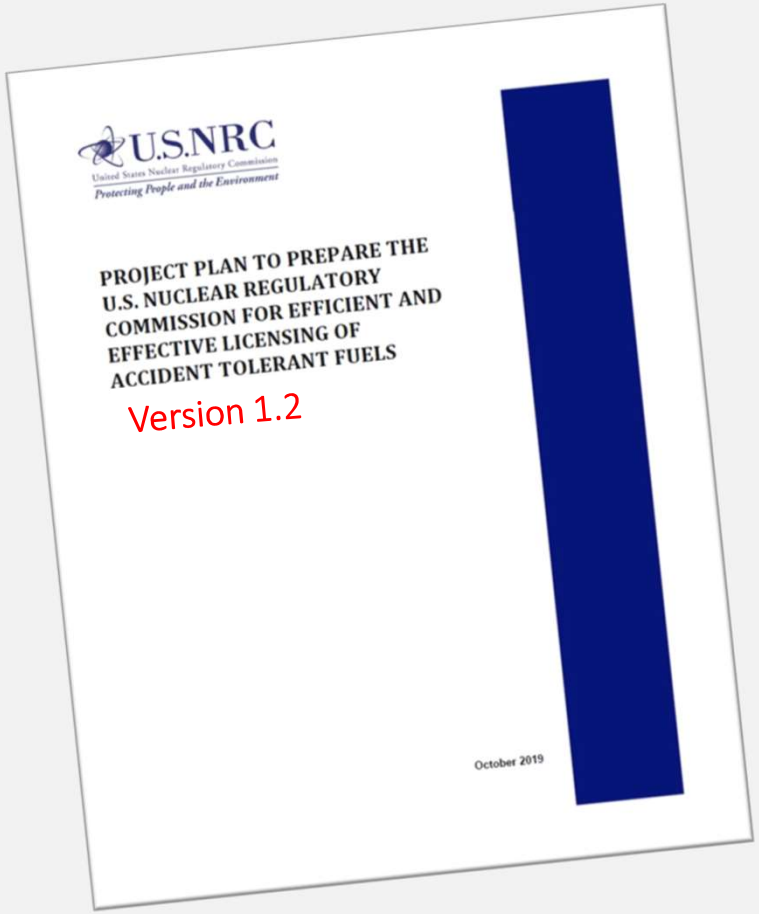
New Paradigm



ATF Project Plan Activities



ATF Project Plan Revision



- Changes to project plan will be updating and streamlining the information provided
- Plan provides a regulatory gap analysis. New revision will expand on gap analysis
- Adding a discussion on the efficiency of the new paradigm
- NRC will issue a draft version and will hold a public meeting in summer 2021
- The new version will be published by Fall 2021

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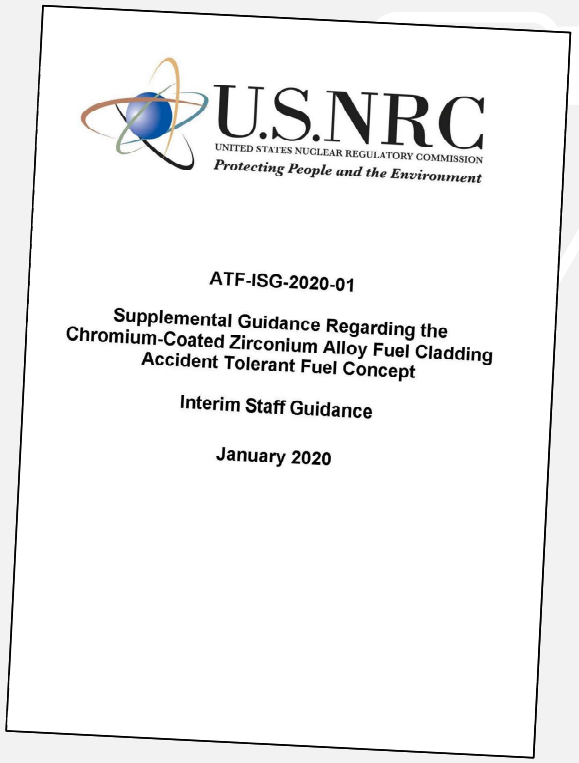
ATF Preparatory Activities

John Wise
Senior Materials Engineer

In-Reactor

Cr-Coated Cladding (and doped fuel)

- Regulatory preparatory activities largely complete; Issued Interim Staff Guidance: ATF-ISG-2020-01
- Remain engaged with fuel vendors prior to their submittal of a topical report for NRC review and approval
- Fuel performance codes continue to be assessed/updated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ATF-ISG-2020-01

Supplemental Guidance Regarding the Chromium-Coated Zirconium Alloy Fuel Cladding Accident Tolerant Fuel Concept

Interim Staff Guidance

January 2020

FeCrAl Cladding

- Anticipate holding an expert elicitation (Phenomena Identification and Ranking Table (PIRT) exercise) when technology readiness has increased and a topical report is being developed
- Decision to issue supplemental staff guidance will follow

Fuel Cycle, Transportation, and Storage

Front End

- UF_6 transportation
- Fuel facilities – enrichment, fabrication
- Unirradiated (Fresh) fuel transportation

Back End

- Irradiated (Spent) fuel storage
- Spent fuel transportation
- Disposal

Regulatory Preparedness Activities

- Identification of critical paths for required regulatory actions
- Research: Technical assessments, confirmatory code development, and expert elicitations (i.e., PIRTs)
- Fuel performance data expected to be obtained by applicants or DOE
- Scope and timelines of activities consistent with industry's targets for batch loading

Front End

UF_6 Transportation

- Existing transportation packages are approved for up to 5% enrichment
- Consideration of 10 CFR 71.55 limit to 5% enrichment – need cylinder water intrusion analysis for higher enrichments or an exemption

Fuel Facilities (Enrichment / Fuel Fabrication)

- All commercial fuel cycle facilities are licensed to produce up to 5% enriched material
- No anticipated challenges for ATF expected enrichments (up to 10%)

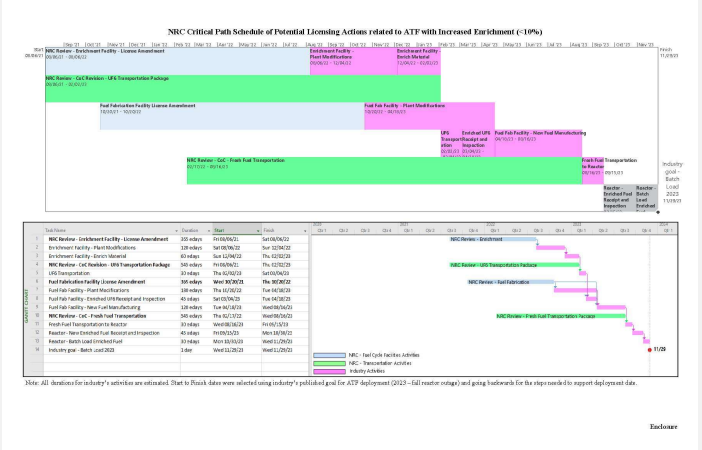
Fresh Fuel Transportation

- The NRC has approved the transportation of limited quantities of ATF for lead test assemblies

Front End – Critical Path

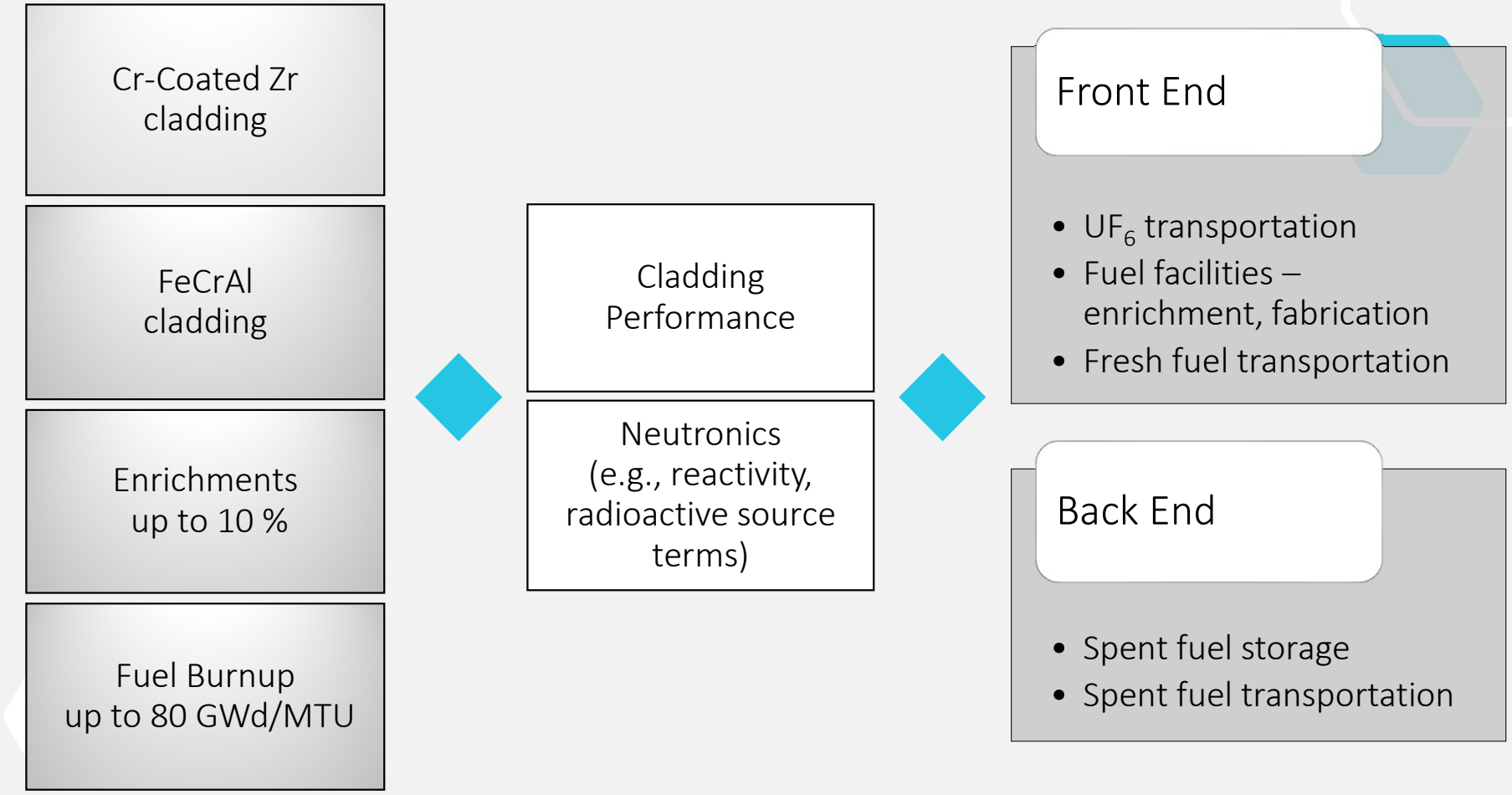
Public letter sent to the Nuclear Energy Institute on critical path timeline to assist mutual understanding with applicants

- Enrichment facility license amendment
- Revised UF_6 transportation package design
- Fuel fabrication facility license amendment
- Revised fresh fuel transportation package design



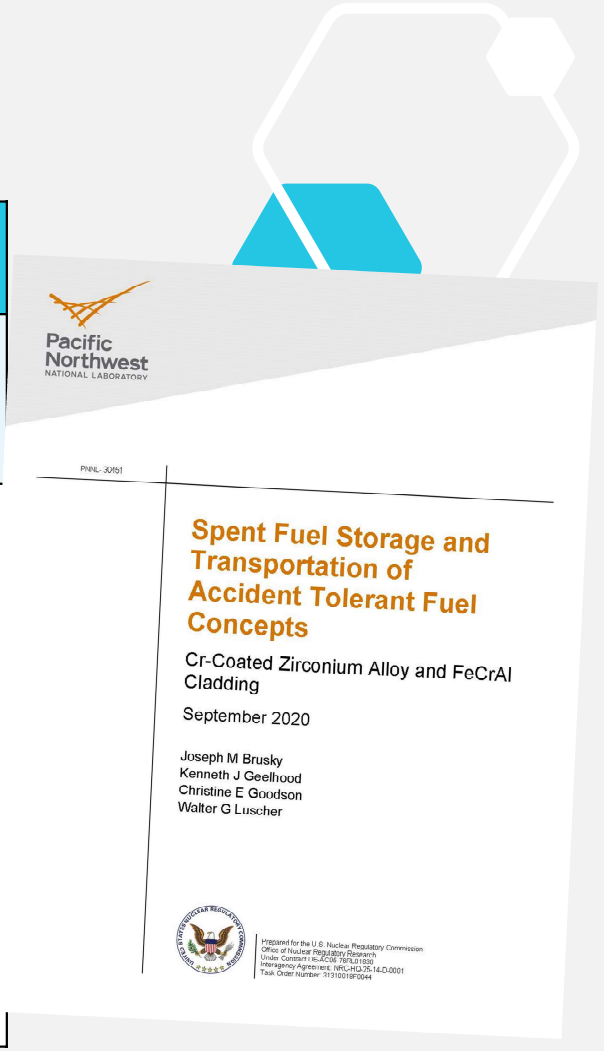
*Kathryn M. Brock (NRC) to Janet R. Schlueter (NEI), "Preparing for Efficient and Effective Licensing of Accident Tolerant Fuel with Higher Enrichment", August 26, 2019 (ADAMS Accession No. ML19235A261)

Research – Front and Back Ends



Cladding Performance

	Activity	Status
Transportation of Unirradiated (Fresh) Fuel	Technical report on fresh fuel transportation of Cr-coated zirconium-based cladding ATF	Complete PNNL-29773*
	Technical report on fresh fuel transportation of FeCrAl cladding ATF	Complete PNNL-30086
Storage and Transportation of Irradiated (Spent) Fuel	Technical report on spent fuel storage and transportation of Cr-coated and FeCrAl cladding ATF	Complete PNNL-30451
	Phenomena Identification Ranking Table (PIRT) exercise on storage and transportation of spent ATF concepts (materials, structural, thermal)	*FY23*

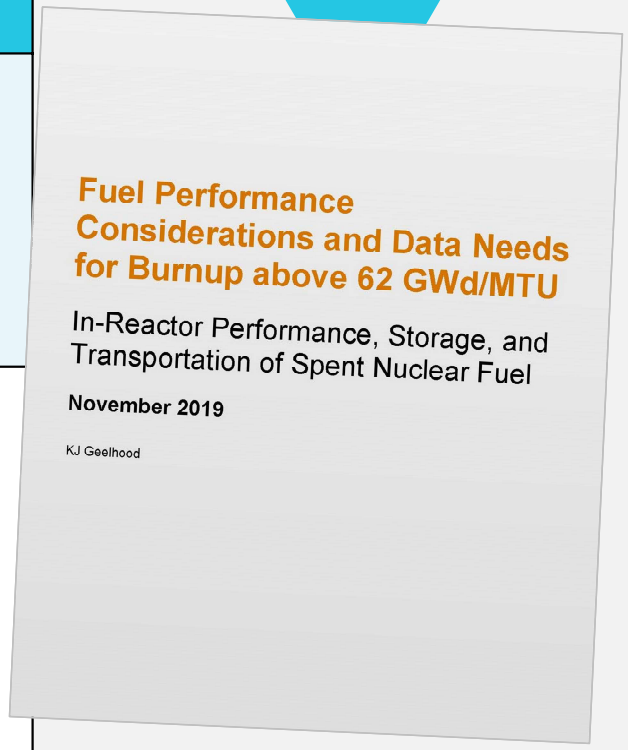


* All reports available at the public NRC ATF website

Cladding Performance

Increased Enrichment and Higher Burnups

	Activity	Status
Standard Fuels (non-ATF) In-reactor, storage, and transportation	Fuel Performance Considerations and Data Needs for Burnup above 62 GWd/MTU	Complete PNNL-29368
Accident Tolerant Fuels	Technical report on data availability and needs for assessing IE/HBU ATF spent fuel performance in dry storage and transportation	*September 2021*
	Fuel performance code updates	



Findings – Fresh Fuel Cladding

Review of open literature:

- Cr-coated Zr alloys
  - Negligible/minimal impacts to cladding mechanical and thermal properties
  - Fatigue endurance may be impacted
- FeCrAl
  - Cladding mechanical and thermal properties expected to be different than zirconium-based alloys
  - Fatigue endurance expected to be different than zirconium-based alloys
- Applicants are expected to supply technical basis in support of their design-basis assumptions
- NRC staff is ready to review applicant-supplied technical basis and will use open literature findings as confirmatory basis

Findings – Spent Fuel Cladding

Cr-coated Zr alloys

- No available information on cladding mechanical and thermal properties
- No available information on fatigue endurance impacts

FeCrAl

- No available information on cladding mechanical and thermal properties
- No available information on fatigue endurance impacts

Technical Information Needs
Spent ATF (Cr-coated, FeCrAl)

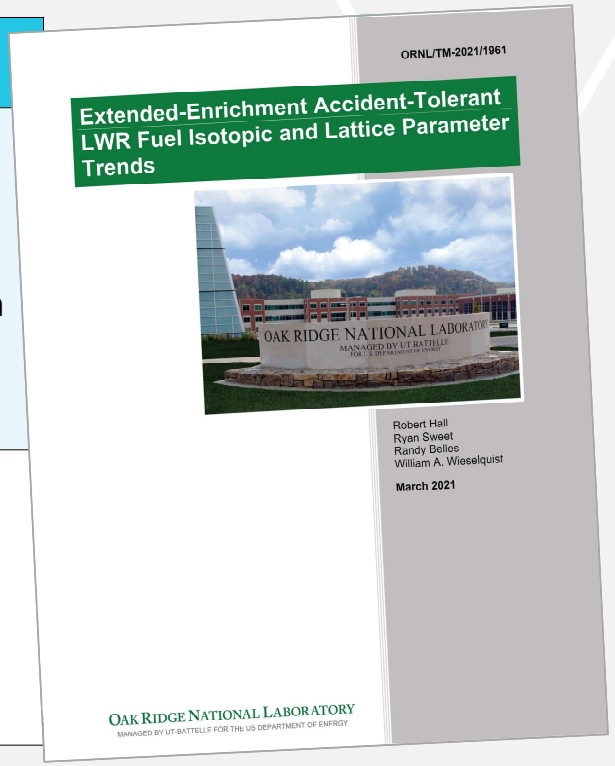
Supporting Information	Recommended Source
• Mechanical properties	Mechanical property tests performed on cladding segments irradiated to target burnup
• Separate effects tests to identify phenomena that can lead to gross cladding rupture	Failure limits at high burnup should be confirmed for creep strain capacity and delayed hydride cracking
• Fatigue life	Fatigue tests performed on cladding segments that contain fuel or have been de-fueled irradiated to target burnup
• Justification for peak cladding temperature limits	Hydride reorientation; ductility and strength tests on cladding segments irradiated to target burnup

Technical Information Needs (cont.)
Spent ATF (Cr-coated, FeCrAl)

Supporting Information	Recommended Source
• Limiting rod internal pressure, oxide thickness, and hydrogen content	Thermal-mechanical code approved to target burnup for rod with limiting power history
• Thermal properties (thermal conductivity, specific heat, thermal expansion)	Thermal property tests performed on cladding segments irradiated to target burnup
• Cladding cross section and activation	Code prediction from code such as ORIGEN

Neutronics (Criticality, Shielding)

	Activity	Status
All portions of fuel cycle	SCALE Code development Evaluations of the impact of increased enrichment and higher burnup on reactivity, decay heat, and radioactive source terms (Oak Ridge National Laboratory)	Several reports complete, others forthcoming through FY23*
Spent fuel storage and transportation	(initial plan) PIRT exercise on storage and transportation of spent ATF concepts with increased enrichment and higher burnup	*No longer being pursued*



* All reports available at the public NRC ATF website

Findings – Criticality and Shielding

- The research has not identified any new neutronics phenomena associated with ATF with increased enrichment and higher burnup that cannot be adequately analyzed with current methodologies
- Gaps remain in the data to validate the neutronics codes at higher enrichments – can be addressed by incorporating new validation data as it becomes available or using conservatisms in the analyses
- Applicants expected to supply criticality and shielding analyses in support of their design basis

Disposal

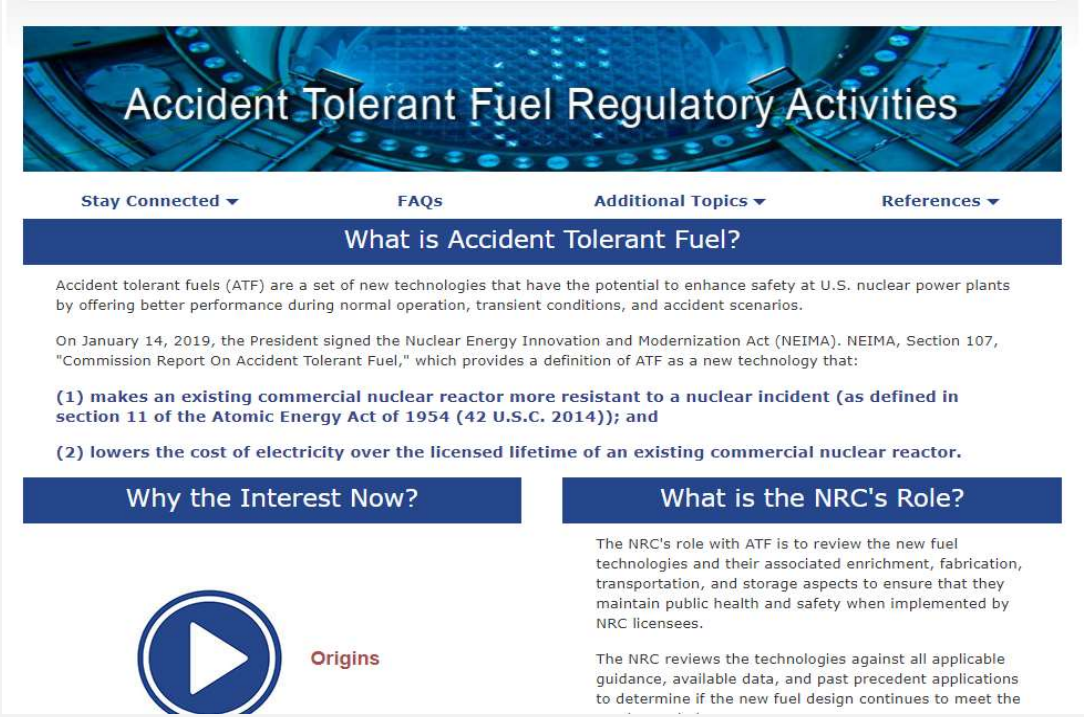
- Preparatory work on ATF disposal is not being pursued at this time
- The need for preparatory activities (e.g., confirmatory research) is continually assessed as ATF technologies develop
- The NRC is not aware of any issues with near-term ATF that would preclude safe disposal
  - Near-term technologies are reasonably similar to current zirconium-based and stainless steel fuels
- Continuing to monitor national and international activities

Concluding Remarks

- The current regulatory framework is adequate for the licensing of ATF cladding, increased enrichment, and higher burnup fuels
- The NRC is following the ATF project plan to facilitate efficient and effective licensing
- The NRC is continuing to assess ATF technologies, higher burnup, and increased enrichment to identify data needs to support licensing
- Opportunities to strengthen regulatory guidance continue to be explored
- To improve the efficiency of regulatory efforts, the NRC encourages applicants to engage early and often

Visit the NRC's ATF Website

https://www.nrc.gov/reactors/atf.html



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