U.S. DEPARTMENT OF ENERGY | Nuclear Energy

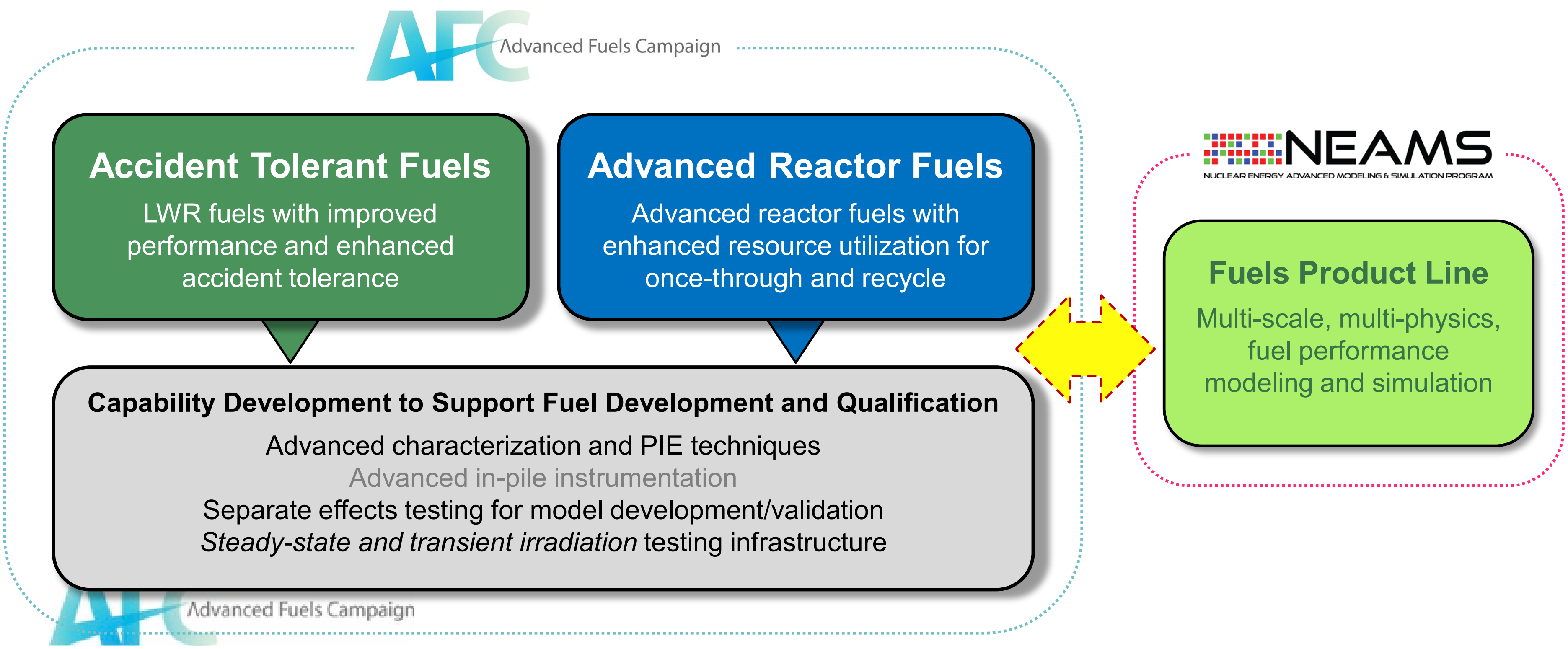
FC 2: Advanced Fuels

Frank Goldner
Program Manager, Accident Tolerant Fuels

DOE-NEUP FY2021 Webinar
August 11, 2020

Advanced Fuels Campaign: Structure and Mission

- **Mission:**
  1) Support development of near-term **Accident Tolerant Fuel** (LWR) technologies
  2) Perform research and development on longer-term **Advanced Reactor Fuel** technologies



FY 2019 NEUP Awards

FY 2019 Nuclear Energy University Program R&D Awards				
Title	**Workscope**	**PI Last Name**	**Lead University**	**Total Budget**
Fuel Cycle Research and Development				
Remote laser based nondestructive evaluation for post irradiation examination of ATF cladding	FC-2.1: Post Irradiation Examination (PIE)/Non-Destructive Examination (NDE) Techniques for Corrosion Thickness Measurements on ATF Claddings (Coated Zr, FeCrAl, SiC)	Yu	University of South Carolina	$ 800,000
Radiation-Induced Swelling in Advanced Nuclear Fuel	FC-2.3: Investigations into Non-Traditional Solid Fuels for Advanced Non-Light Water Reactors	Lang	University of Tennessee at Knoxville	$ 799,989
High throughput assessment of creep behavior of advanced nuclear reactor structural alloys by nano/microindentation	FC-2.4: Advanced Creep Testing of Ferritic Steels for Reactor Cladding Applications	Mara	University of Minnesota, Twin Cities	$ 800,000
Novel miniature creep tester for virgin and neutron irradiated clad alloys with benchmarked multiscale modeling and simulations	FC-2.4: Advanced Creep Testing of Ferritic Steels for Reactor Cladding Applications	Murty	North Carolina State University	$ 800,000
Thermal Conductivity Measurement of Irradiated Metallic Fuel Using TREAT	FC-2.5: Separate Effects Testing in TREAT using Standard Test Capsules	Ban	University of Pittsburgh	$ 500,000
Neutron Radiation Effect on Diffusion between Zr (and Zircaloy) and Cr for Accurate Lifetime Prediction of ATF	FC-2.5: Separate Effects Testing in TREAT using Standard Test Capsules	Zhao	The Ohio State University	$ 499,997

FY 2020 NEUP Awards

Linear and nonlinear guided ultrasonic waves to characterize cladding of accident tolerant fuel (ATF)	CFA-20-19660	FC-2.1: NDE Techniques for Assessing Integrity of Coated Cladding Tubes	Laurence	Jacobs	Georgia Institute of Technology	$800,000
Chemical Interaction and Compatibility of Uranium Nitride with Liquid Pb and Alumina-forming Austenitic Alloys	CFA-20-19627	FC-2.2: Investigations of Carbide and Nitride Fuel Systems for Advanced Fast Reactors	Jie	Lian	Rensselaer Polytechnic Institute	$800,000
Femtosecond Laser Ablation Machining & Examination - Center for Active Materials Processing (FLAME-CAMP)	CFA-20-19545	FC-2.3: High-Throughput and/or Micro-Scale Post-Irradiation Examination Techniques to Support Accelerated Fuel Testing	Peter	Hosemann	University of California, Berkeley	$800,000
Maintaining and building upon the Halden legacy of In-situ diagnostics	CFA-20-19374	FC-2.4: Maintaining and Building upon the Halden Legacy of In Situ Diagnostics	Michael	Corradini	University of Wisconsin-Madison	$800,000
Investigation of Degradation Mechanisms of Cr-coated Zirconium Alloy Cladding in Reactivity Initiated Accidents (RIA)	CFA-20-19076	FC-2.5: NSUF Separate Effects Testing in TREAT using Standard Test Capsules	Hwasung	Yeom	University of Wisconsin-Madison	$500,000

FC 2.1 – Fuel-to-Coolant Thermomechanical Transport Behaviors Under Transient Conditions

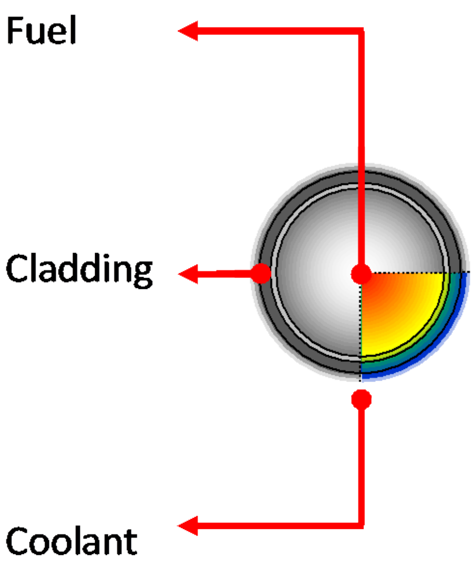
Federal Manager: Frank Goldner

Technical POC: Colby Jensen, INL

- **DOE is working with industry to perform R&D to enable licensing Accident Tolerant Fuels and extending burnup licensing limits beyond 62 GWd/MTU.**
- **Fuel performance during operational and accident transient conditions is an important R&D opportunity area to support fuel qualification and extend licensable limits.**
  - Inadequate characterization of transient Fuel-to-Coolant (F2C) transport behaviors (both qualitatively and analytically) often poses a challenge to predicting and/or explaining the associated material response.
  - Integral experiments for fuel performance during transients are being developed and performed at the Transient Reactor Test (TREAT) facility for testing irradiated fuels
- **Improved understanding and predictive capabilities for a variety key phenomena relevant to LWR transients will provide expand opportunities for achieving maximum performance and expanded fuel utilization.**

FC 2.1 – Fuel-to-Coolant Thermomechanical Transport Behaviors Under Transient Conditions

- **Fuel-to-Coolant (F2C) thermomechanical transport behaviors include a variety of mechanisms for thermal or mechanical energy transport between the fuel/cladding/coolant**
  - Oftentimes requiring multiphysics coupling of fuel performance and thermohydraulic modeling & simulation tools
  - Phenomena of interest typically span multiple reactor transients from operational to design basis accidents.
  - In all cases, it boils down to understanding and developing models to describe energy transfer from the fuel through the cladding to the coolant and, in some extreme cases, directly from fuel to coolant
  - RIA and LOCA examples shown on next slide



FC 2.1 – Fuel-to-Coolant Thermomechanical Transport Behaviors Under Transient Conditions

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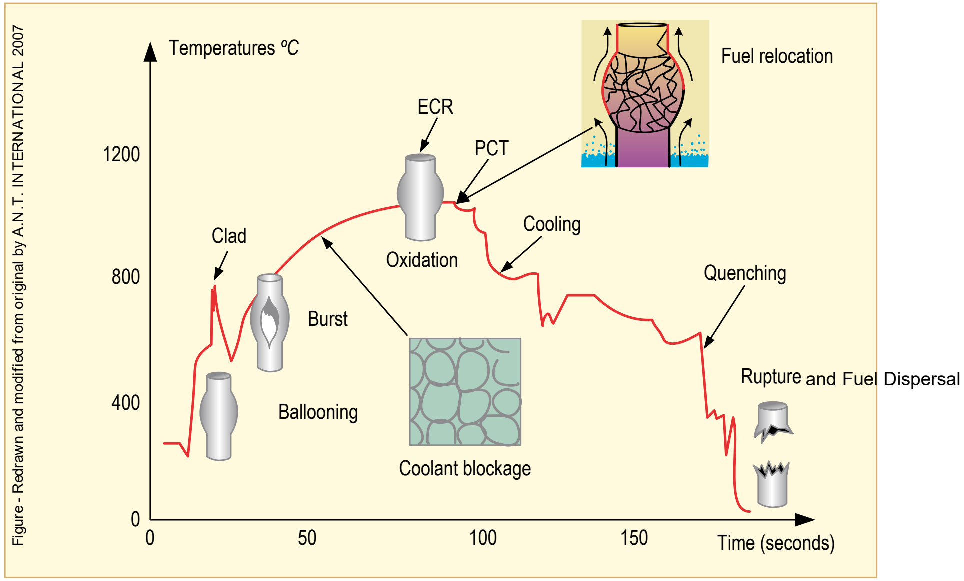
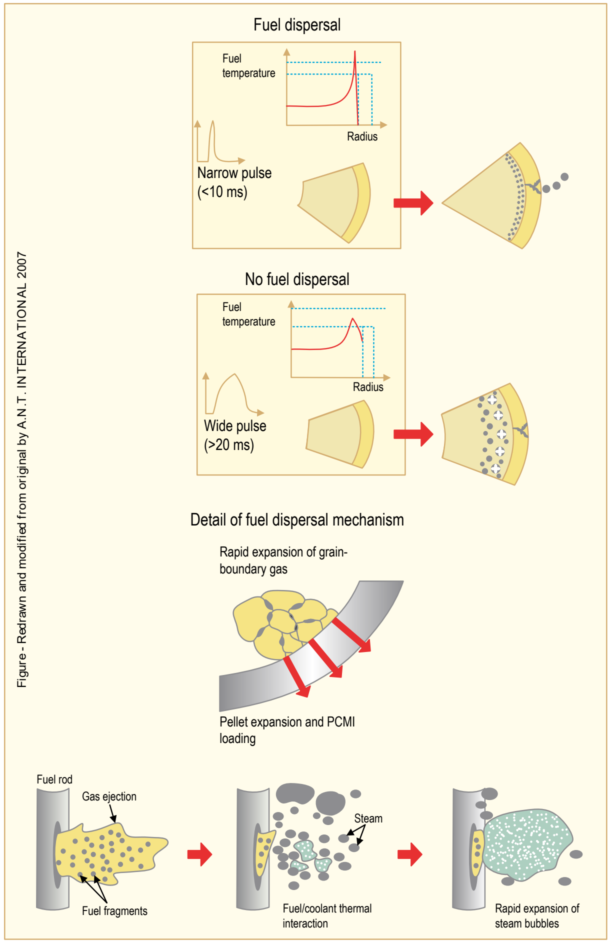
- **Examples of phenomenological evolution for design basis accident transient conditions (could include operational events as well)**





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FC 2.1 – Fuel-to-Coolant Thermomechanical Transport Behaviors Under Transient Conditions

- **This call seeks proposals including experimental and/or modeling scopes that will extend current understanding and prediction of F2C transport behaviors, thermal and/or mechanical, *during transient conditions relevant to nuclear fuel operations and safety*.**
  - Transient conditions and corresponding phenomena selected for study must show clear connectivity to meaningful impacts to industry through opportunities for qualifying expanded fuel performance limits.
- **Proposals should focus on clear applications to near-term Accident Tolerant Fuels (ATF) concepts and high burnup fuel (>62 GWd/MTU).**
- **Proposals should show clear connectivity of separate effects experimental studies and modeling to integral behaviors (preferably in-pile integral experiments, planned or historical where applicable).**
  - Planned experiments at TREAT include AOO (short duration DNB/dryout type), RIA, and LOCA experiments.
  - Historical data could be used where available
  - A clear explanation should be provided if this is not possible and outcomes should include the description of an in-pile integral experiment that would)
- **Proposals are encouraged to consider coordinating findings with the NEAMS program so that models can be incorporated into relevant tools.**

FC 2.2 – High Burnup LWR Fuel Rod Behavior under Normal and Transient Conditions

Federal Manager: Frank Goldner

Technical POC: Nathan Capps, ORNL

- **Nuclear Industry is looking to extend peak rod average burnup limits above the current regulatory burnup limit, 62 GWd/MTU, with increased enrichment**
  - Current LWR fuel (Zr/UO_2) and ATF concepts are under consideration for burnup and enrichment extension
- **LWR fuel (Zr/UO_2) and ATF concepts are expected to meet all the current safety criteria for burnup extension**
- **ATF concepts are expected to provide safety enhancements that lead to additional economic benefits**

FC 2.2 – High Burnup LWR Fuel Rod Behavior under Normal and Transient Conditions

- The objective of this call is to encourage proposals aimed to improve our ability to predict and model high burnup (i.e. >62 GWd/MTU) fuel rod response and behavior under normal and transient conditions.
- The primary focus should be to investigate those conditions that might be most limiting under normal and transient conditions, e.g. rod internal pressure and fission gas release, and evaluate potential test irradiation conditions that would eventually be conducted to provide data to fill the most critical gaps in predicting fuel performance.
- Accident Tolerant Fuels should be investigated in order to evaluate the additional safety margin in comparison to current Light Water Reactor fuels.
- It is anticipated that novel experimental measurements and/or modeling approaches will be necessary to address this challenge.
- Proposals should consider how these methods and datasets accelerate and inform the safety case. It is anticipated that proposals will not require test irradiations. However, characterization of irradiated materials may be considered.
- Proposed experimental investigations may consider using surrogate materials, but the proposal must make a strong case as to why the information collected through use of surrogate material is applicable to the mechanisms governing the fuel response.

FC 2.2 – High Burnup LWR Fuel Rod Behavior under Normal and Transient Conditions

- **Proposals Goals:**
  - Improve our ability to predict and model high burnup (>62 GWd/MTU) fuel rod response and behavior under normal and transient conditions
  - Identify fuel rod conditions that might be most limiting (e.g. fission gas release, rod internal pressure, fuel temperatures, etc.)
  - Identify safety margin afforded by ATF concepts
- **Applicants should consider:**
  - Novel experimental measurements and/or modeling approaches (i.e. mechanistic modeling) to inform analyses
    - *Material characterization of irradiated materials may be considered*
  - Discuss how these methods and datasets will accelerate and inform the safety case and margin identification
- **Applicants should not consider:**
  - Developing new safety/licensing criteria
  - Experiments requiring test irradiations
- **Expected Deliverables:**
  - Journal Publications

Contact Information

- **AFC National Technical Director:**
  - Steve Hayes(INL), steven.hayes@inl.gov
- **Federal Program Managers:**
  - Frank Goldner, frank.goldner@nuclear.energy.gov
- **Technical Leads:**
  - Colby Jensen (INL), colby.jensen@inl.gov
  - Nathan Capps (ORNL), cappsna@ornl.gov

- **Please review previous fuel related awards at www.neup.gov.**

Background Information

Advanced Fuels Website

https://nuclearfuel.inl.gov/afp/SitePages/Home.aspx

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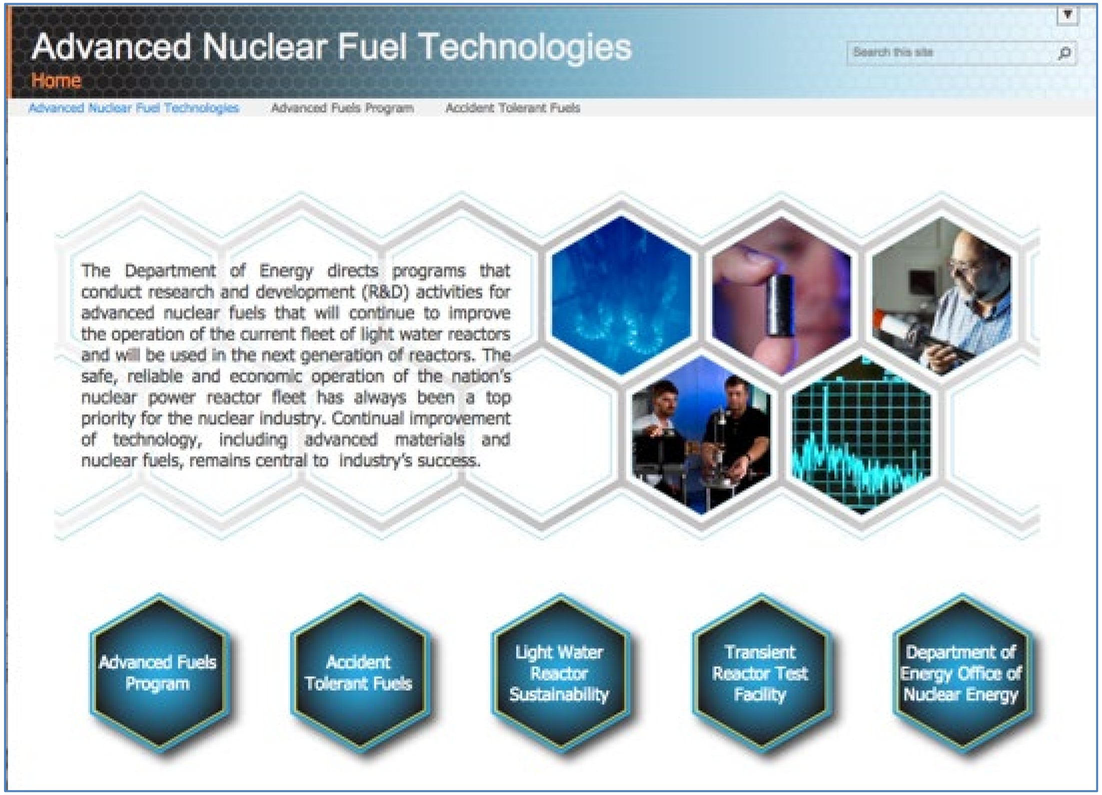

Accident Tolerant LWR Fuel Information Sheet

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NEUP Nuclear Energy University Programs

U.S. Department of Energy

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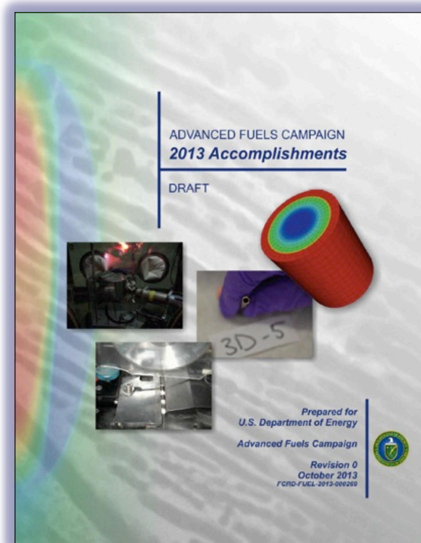
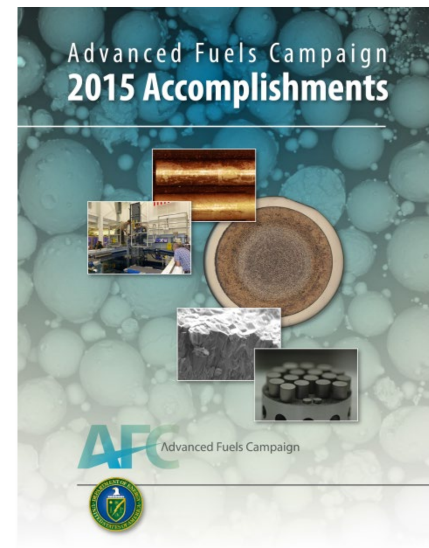
Recent Advanced Fuels Campaign Documents – Available on OSTI

OSTI Document Links of Interest:

Overview of Accident Tolerant Fuel Program
http://www.osti.gov/scitech/servlets/purl/1130553

Accident Tolerant Fuel Performance Metrics
http://www.osti.gov/scitech/servlets/purl/1129113





Advanced Fuel Cycle Web Site:
https://nuclearfuel.inl.gov/afp/SitePages/Home.aspx

2019 Accomplishments Report
https://nuclearfuel.inl.gov/afp/2019%20Accomplishments%20Report/index.aspx?page=1

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