IRUG 2019

RELAP5-3D Application to Risk-Informed Systems Analysis

LWRS LIGHT WATER REACTOR SUSTAINABILITY

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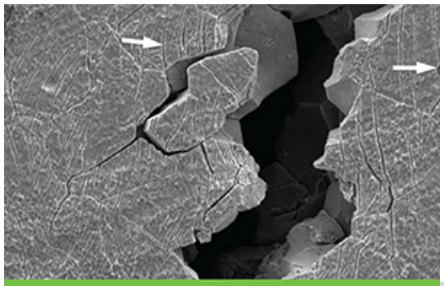
Light Water Reactor Sustainability (LWRS)

- **Support for safe and economic long-term operation of US NPPs**
  - Sponsored by U.S. DOE, coordinated with US nuclear industry and stakeholders
  - Conduct R&D to develop technologies and solutions for sustainable nuclear energy
- **Program objectives**
  - Provide science and technology based solutions to industry originated issues
  - Manage aging systems, structures and components (SSC) for safe and economic NPP operation
- **Three large R&D pathways (FY19)**
  - Material research
  - Plant modernization
  - **Risk informed systems analysis**

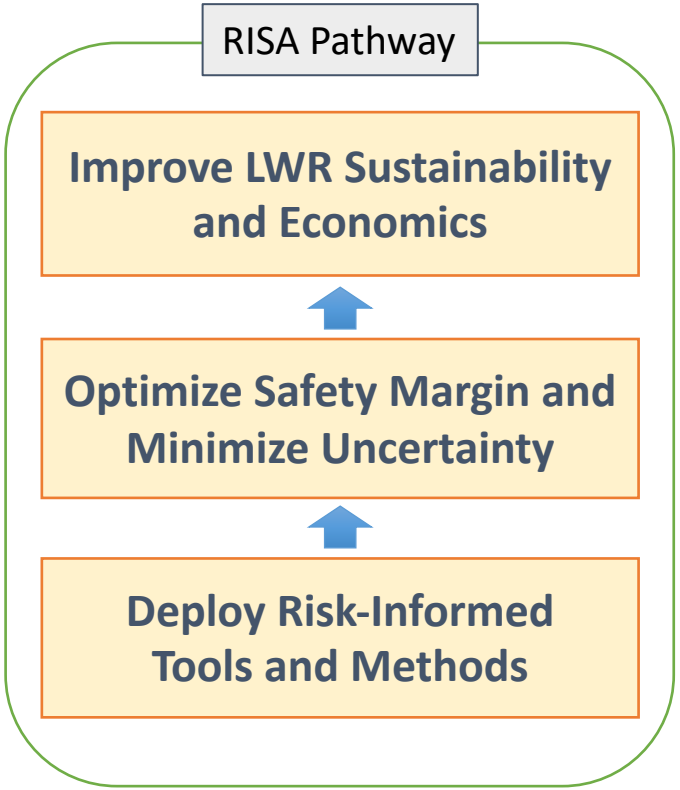

Materials Research


Plant Modernization


Risk-informed Systems Analysis

Risk-Informed Systems Analysis (RISA) Pathway Mission and Goals

- **Mission**
  - R&D to optimize safety margins and minimize uncertainties to achieve high levels of safety & economic efficiencies
- **Goals**
  - Deploy risk-informed tools and methods to US nuclear industry (*the what*)
    - Overcome issues with legacy methods and tools
    - Improve economics, reliability, and sustain safety during extended operations
  - Conduct industry-engaged risk-informed applications (*the how*)
    - Collaborate with industry for margin management strategies development
    - Facilitate risk-informed technology transfer to industry



Concept of *Risk-Informed* Framework

Benefits of Risk-informed Approach

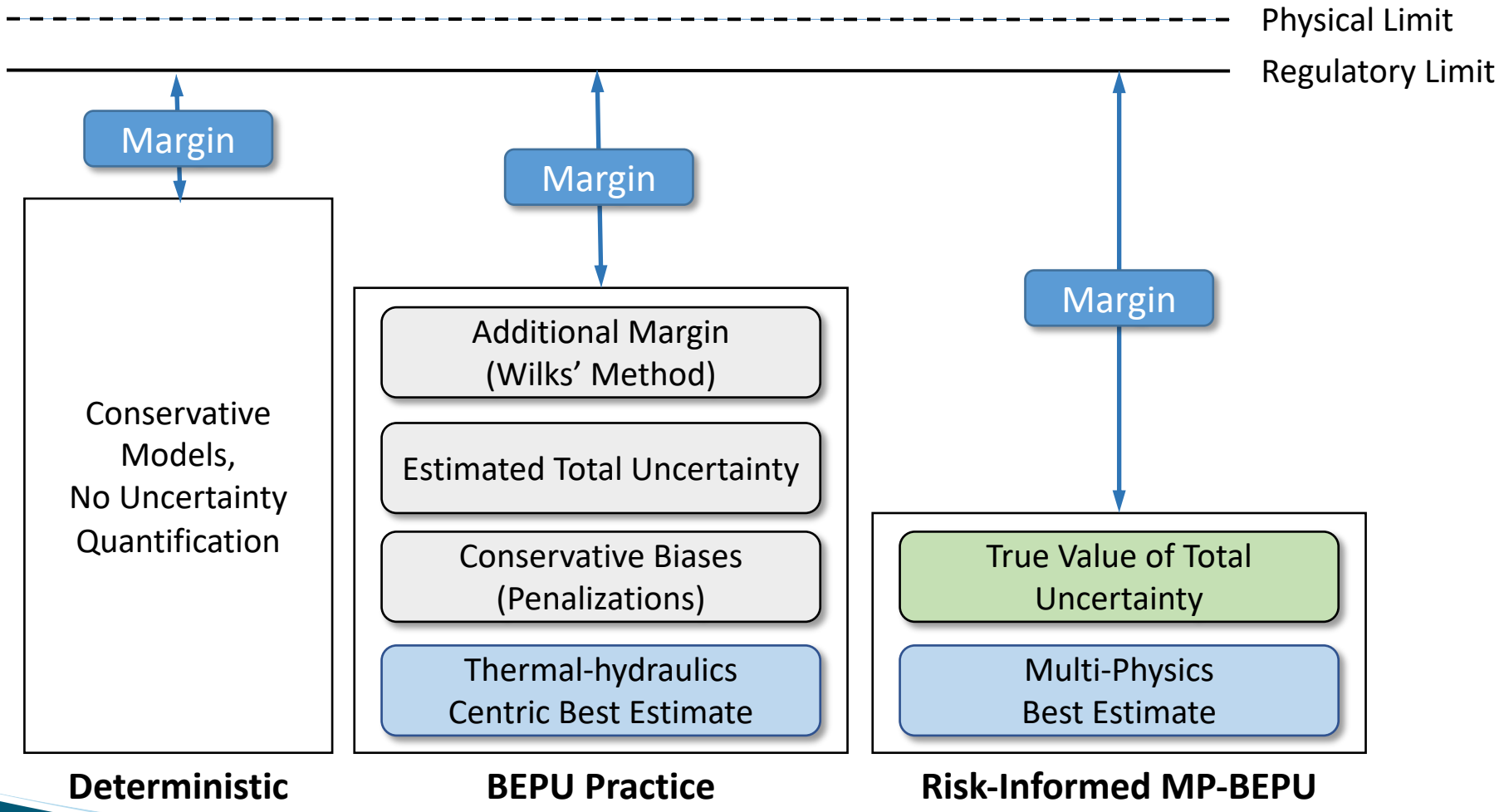
"Science based **margin optimization** and **minimize over-conservatism**"

"Support risk-informed **licensing** and regulatory system development"

"Consequently, **improves safety and economics** for longer-term operation"

* NRC Risk-Informed and Performance Based Initiatives, Commissioner George Apostolakis, April, 30, 2013

Example of risk informed approach



Risk-Informed Systems Analysis Work Scope

Risk-Informed Systems Analysis (RISA)

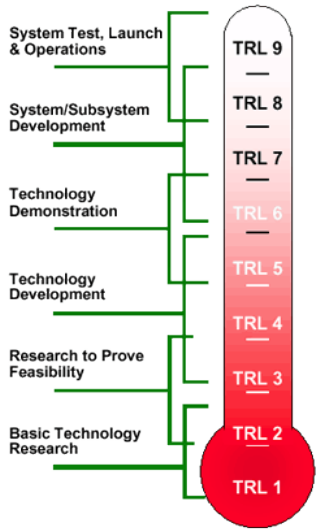
Methods	Tools	Data
Risk	Materials, Aging	Assessment, Verification & Validation
Cost	PRA	Experiments
Reliability	Advanced Risk Assessment	Uncertainty Quantification
Multi-physics /-scale BEPU	Core Design, Fuels Performance	
Dynamic / Integrated Analysis	DBA / Severe Accidents	
	Fire, Seismic, Flood, Wind	

BEPU = best-estimate plus uncertainty
PRA = probabilistic risk assessment
DBA = design basis accident

Pilot Projects → **US Nuclear Industry**

4-Step Deployment Strategy

- **Problem definition**
- **Confirm tools and methods**
- **Preliminary pilot (TRL 4-5)**
- **Full Analysis pilot (TRL 5→7)**



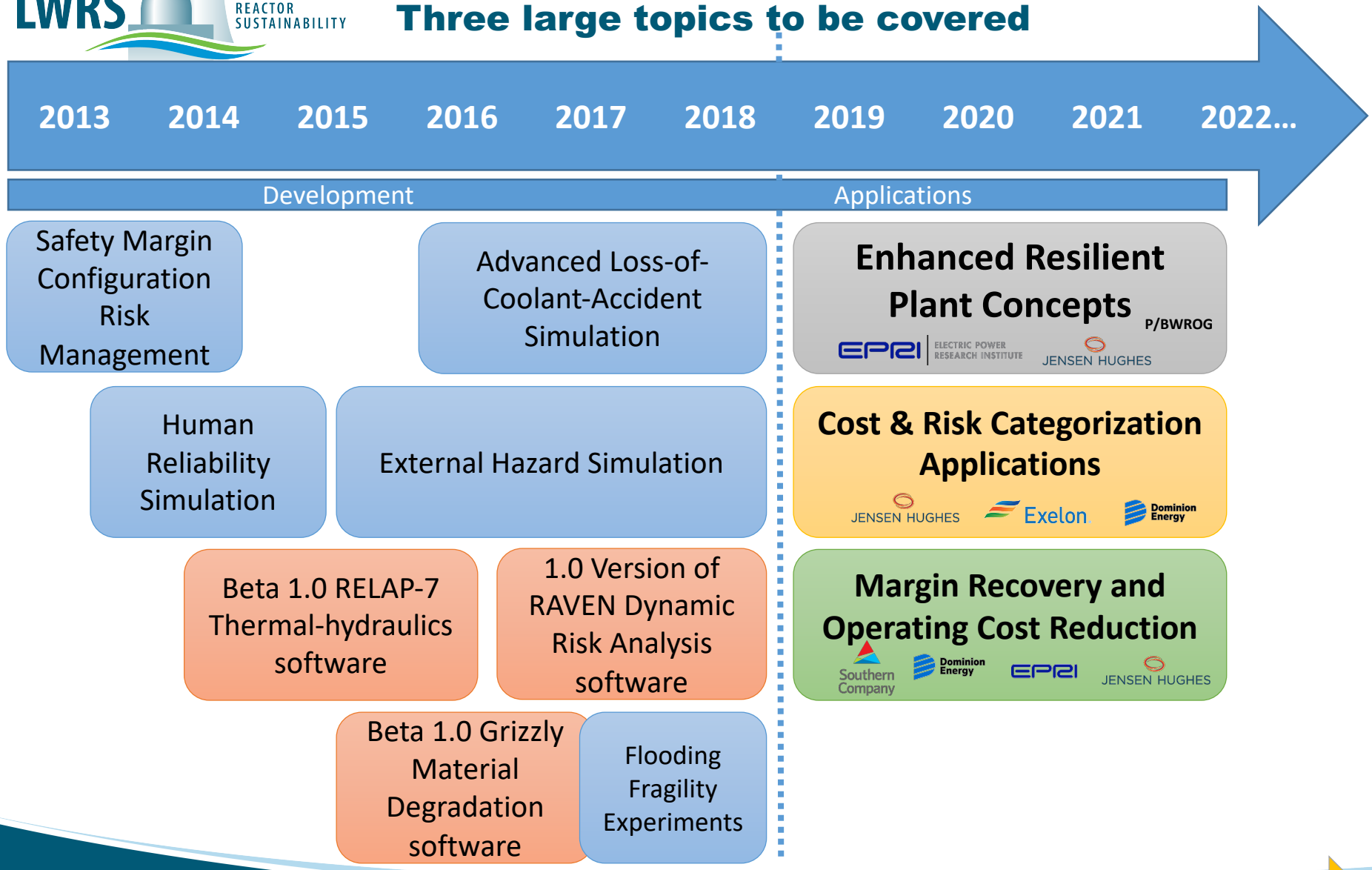
Business development and deployment by mature industry

Focused R&D by highly technical organizations

NASA **T**echnology **R**eadiness **L**evels

LWRS LIGHT WATER REACTOR SUSTAINABILITY

Three large topics to be covered



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Tools possibly used in risk informed analysis

Core Design	VERA-CS			
Fuel Performance	FRAPCON/FRAPTRAN	BISON		
System Analysis	RELAP5-3D	RELAP-7		
Containment	MELCOR			
Severe Accident	MELCOR			
Material Aging	GRIZZLY			
Natural Hazards	MASTODON	NEUTRINO	CFAST	FDS
PRA	SAPHIRE	RAVEN	EMRALD	HUNTER
Code Integration	LOTUS	RAVEN		
Cost & Economics	CRAFT	RAVEN		

Programs using RELAP5-3D

- Enhanced Resilient Plant Systems
  - Integration of enhanced safety systems: Accident Tolerant Fuel, Diverse and Flexible Coping Strategies (FLEX), Passive cooling system
  - RELAP5-3D/RAVEN coupling for ATR by D. Mandelli
  - RELAP5-3D for ATF present by C. Parisi
  - Planed RELAP5-3D analysis of passive cooling system
- Enhanced Operation Strategies for System Components
  - Analysis of Terry turbo-pump behavior under beyond DBA
  - Plan to improve RELAP5-3D computational capability on Terry turbine
- Modernization of DBA Analysis with Application on Fuel Burnup Extension
  - Develop risk-informed safety analysis model for higher burn-up operation
  - RELAP5-3D transient analysis for new fuel/core configuration

Programs using RELAP5-3D

- Digital Instrumentation and Control (I&C) Risk Assessment
  - Develop risk assessment method for digital I&C integration to NPP
  - Transient and accident analysis with RELAP5-3D
  - Plan to develop RELAP5-3D capability for using Multi-Physics BEPU modeling
- Plant Reload Process Optimization
  - Development of fuel reloading licensing process optimization method
  - RELAP5-3D for system analysis under risk informed fuel thermal limit analysis
- Assessment of risk informed tools and methods
  - Maturity and V&V status assessment of tools and methods
  - RELAP5-3D for FY2019

More programs will be developed and looking for use of RELAP5-3D

Major Outcomes of the RISA Pathway

- **Risk-Informed Systems Analysis (RISA) will**
  - Deploy and update risk-informed tools & methods
  - Enhance plant resiliency
    - Increase coping time and safety margins, decrease plant damage frequency, and improve operational economics
  - Focus on intersection of risks & costs
    - Expand the risk-informed technology on maintenance cost saving and license renewal
  - Recover safety margin & reduce operational cost
    - Assess and optimize margins of extended burnup operation, thermal limit of fuel reloading, external hazard analysis, and digital I&C implementation
  - Communicate & support validation
    - Collect and update industry needs and emerging issues

The RISA Pathway working to deploy validated risk-informed systems analysis tools and methods to US nuclear industry to improve economics, reliability, and sustain safety during extended plant operations

Sustaining National Nuclear Assets

http://lwrs.inl.gov