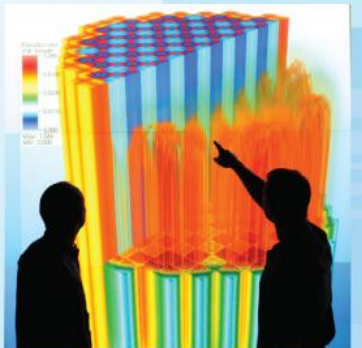
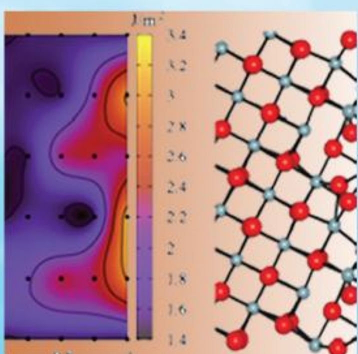
CASL-U-2012-0011-000

Power uprates
and plant life extension

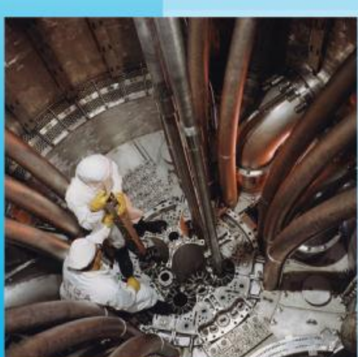


Engineering design
and analysis

Science-enabling
high performance
computing



Fundamental science



Plant operational data

CASL
Consortium for Advanced Simulation of LWRs

L3:AMA.RX.P4.01

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U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Power Uprate Limitation Assessment

Milestone Deliverable – AMA.RX.P4.01

1 Introduction

This is a follow-on task of an AMA Level 3 milestone (AMA.RX.P3.01) delivered during POR-3 to further assess the LWR power uprate limitations and align CASL work to facilitate additional power uprates.

A power uprate workshop was held at ORNL in September 2011. A comprehensive list of obstacles/issues confronting LWR power uprates had been developed during the workshop. The majority of the issues are the legacy of unresolved analytical issues that CASL can contribute to resolve. Table 1 shows the list of issues that have their importance ranked.

Table 1. Identified Obstacles to Power Uprates and Workshop Participant Rating on Relative Importance

Issue or Obstacle to Power Uprate	Importance
Post-LOCA boric acid precipitation	High
Rod ejection, new NRC criteria, 3D analyses and detailed pin census	High
Higher fidelity coupled LOCA transients	High
Coupled code methodology to reduce conservatism	High
24 month cycles (trade off with uprate) fuel reliability margins (higher power fuel higher density fuel higher burnup fuel core loading studies)	High
Beyond 60 year lifetime extension	High
Cooling water issues with power uprates	
GSI-191	High
Power distribution uncertainties (BWR)	High
Void coefficient impacts (BWR)	High
Applicability of void quality correlations (BWR)	High
Bypass voiding (BWR)	High
Post-LOCA containment pressure	High
High void neutronics modeling (BWR)	High
Anticipated Transient Without Scram (ATWS) (Instability for BWRs)	High

Increased irradiation-assisted stress corrosion cracking of core internals	Med
Non-lOCA transients	Med
Optimized core operating and loading parameters	Med
Reactor internals structural – steam dryers (BWR), core plates, baffles, BWR core shrouds	Med
Vessel fluence and gamma heating	Med
Distortion (rod and assembly bow)	Med
DNBR correlations/calculations	Med
Numerical methods and computation time	Med
Reactor internals structural (dryer, core plates, baffles, shrouds, annulus pressurization loads, etc.)	Med
Spent fuel pool criticality margin	Med
Seismic and LOCA loads	Med
Centerline Fuel Melt calculations	Low
Steam generator tube rupture single failure analysis	Low
Flow-accelerated corrosion (BOP)	Low

This assessment further explores each of the uprate obstacles categorized as “high” or “medium” importance during the workshop with respect to:

- identifying areas where CASL already intends to provide solution through the project as it already exists, and

- identifying high priority power uprate obstacles that CASL can effectively address with only minor changes to the project.

The degree to which the existing CASL project is expected to address each uprate obstacle and the expected timeframe (first 5 years or second 5 years of the CASL project) is discussed for each of the high or medium importance uprate obstacles, and where applicable modifications to the CASL project are suggested to support resolution of the obstacle.

2 LWR Power Uprate Limitation Assessment

A number of activities have taken place following the workshop to further digest the information and better identify more precisely the areas of development that CASL should target. We have engaged all the six focus areas of CASL and gathered their input on how each focus area will be able to impact the obstacles listed in Table 1. The inputs gathered from all the focus areas on their respective ability to address those obstacles are shown in Appendix A. We also have in-depth discussions with Gregg Swindlehurst from GS Nuclear Consulting LLC on the various issues. Gregg had 30 years experience with nuclear power plants working for Duke Energy. He had contributed to the original power uprate workshop.

2.1 First Five Year Time Frame of CASL

Table 2 shows the obstacles CASL can impact during the 1st five years of timeframe.

Table 2. Identified Obstacles to Power Uprates and Ability of CASL to Impact during the 1st Five Years

Issue or Obstacle to Power Uprate	Importance	Ability of CASL to Impact
Coupled code methodology to reduce conservatism	High	High
Rod ejection, new NRC criteria, 3D analyses and detailed pin census	High	High
Higher fidelity coupled LOCA transients	High	High
24 month cycles (trade off with uprate) fuel reliability margins (higher power fuel higher density fuel higher burnup fuel core loading studies)	High	High
Numerical methods and computation time	Med	High
ATWS	Med	High
Optimized core operating and loading parameters	Med	High
Vessel fluence and gamma heating	Med	High

1. **Coupled code methodology to reduce conservatism**: The current industry practice uses computer codes that were developed for specific physics such as neutronics codes, thermal hydraulics codes, structural mechanics codes, fuel performance codes, etc. Since the codes are not coupled, some conservatisms have been applied within boundary conditions and material modeling. Coupled code calculations allow the simulations to be more representative of the physical phenomena (best estimate versus a conservative bounding approach) and the conservatism can be identified and potentially exploited for power uprates. Since one of the primary objectives of CASL is to couple individual physics codes, CASL's work aligns naturally with resolving this obstacle. It is expected that CASL will provide tools to apply towards this obstacle within the first 5 years of the project.

2. **Rod ejection, new NRC criteria, 3D analyses and detailed pin census**: One of the most challenging reactivity-initiated accidents (RIA) for PWRs is a control rod ejection accident. A control rod ejection can occur by mechanical failure of the control rod drive mechanism or its housing, and as a consequence of the rod ejection, the reactivity of the core can very rapidly increase. This also results in a rapid core power excursion with locally high energy deposition in the fuel, which can lead to various fuel failure mechanisms such as brittle-mode clad failure, pellet melting and long term local coolant boiling that leads to clad ballooning and creep rupture. Thus, the local change in fuel pellet enthalpy is an important parameter during a reactivity-initiated accident (RIA). The most important safety parameter of reactivity initiated accident (RIA) is the maximum local fuel pellet enthalpy, which establishes the acceptance criterion for unacceptable fuel damage in RIAs. The spatial effects play an important role in the RIAs, in particular, the core peak power and energy deposition, which is approximately the fuel enthalpy rise under an adiabatic assumption. Therefore, to determine a peak value of this parameter accurately, it is necessary to consider 3D transient pin-by-pin neutronics, 3D two-phase core mixing, 3D core and upper plenum boiling and condensation, as well as 3D post-DNB ballooning and rupture. The new NRC criteria (exposure-dependent limits on fuel enthalpy rise)) place more emphasis on pellet clad mechanical interaction (PCMI) and consequently required more detailed analyses of RIA events. The current practice mostly is to use the 1D or 2D very conservative kinetics methodologies. Even in the current best-estimate 3D nodal diffusion methods such a problem is usually split into two steps: first – a calculation of assembly-average power distribution, and second – peak power estimate within selected fuel assemblies by a pin-by-pin reconstruction method with further estimate of the peak local fuel enthalpy. This procedure has evident drawbacks compared with the direct pin-by-pin methods which CASL is developing, especially when spatial effects are very complicated during the event. The 3-D neutronic codes being developed by CASL such as Denovo and Decart will be able to provide very high fidelity calculations of maximum local fuel pellet enthalpy. However these methods do not guarantee conservative estimation in key safety parameters during RIA. It is important to determine the uncertainty in fuel enthalpy calculated by these codes. DNB

analysis including post DNB effects will be required for rod ejection. The CASL's VERA suite of codes provides the advanced tools to address such an obstacle.

*Recommendation to CASL: 1).*Ensure that transient capabilities are developed within CASL radiation transport, thermal-hydraulic and fuel rod mechanics codes (target end of second 5 years). 2). Further develop specifications and scope for CASL RIA challenge problem.

3. **Higher fidelity coupled LOCA transients**: LOCA transients are extremely important in evaluating reactor response. LOCA analysis requires a systems analysis code development which is beyond CASL's currently published scope. Thus, this power uprate limitation cannot be effectively addressed by the CASL project. However, CASL can provide interfaces such that others can build on VERA for LOCA applications. Thus, the following CASL project tasks are recommended:
   - Add a task to develop an interface strategy between VERA and RELAP.
   - Add a requirement for appropriate RELAP interface points to be included in VERA.

   For the issues outside the vessel, it is recommended that CASL takes the "opportunistic" approach and to leverage other DOE sponsored efforts (e.g. RELAP7) to address selected issues.

4. **24 month cycles (trade off with uprate) fuel reliability margins (higher power fuel higher density fuel higher burnup fuel core loading studies):** It was noted at the workshop that this item isn't a direct obstacle to uprates; however, 24-month cycles are highly desirable and currently they are considered to be incompatible with uprated Westinghouse 4-loop plants. With the current mature fuel design and 5% enrichment limit, 24 month cycle is not economical for four-loop Westinghouse plants because 50% of the fuel assemblies will have to be reloaded during each refueling outage. More innovative fuel design (e.g. to overcome the 5% enrichment limit) or more innovative core design (e.g. converter design) would be required to achieve 24 month cycles. Hence, CASL's impact for this will be to develop predictable fuel performance analysis tools to reduce the efforts required for irradiation testing to speed up the advanced fuel design and to shorten the time required to bring new designs to commercial applications. VERA suite of codes and especially the advanced fuel performance code Perigrine will fulfill such mission. However, a notable gap in the VERA suite of tools is a lack of a fully functional core simulator that can support such innovative fuel and core designs.

   Recommendation to CASL: Develop fully functional core simulator to establish capability to perform reactor cycle calculations and ability to evaluate design and safety margins.

5. **Numerical methods and computation time**: CASL aims at developing VERA tools for LWRs that would take advantage of today's leadership-class computers, advanced architecture platforms now under development by DOE, and the engineering workstation of the future. Clearly, the VERA tools will require the computing power that is far beyond what industry has. However, the high-fidelity coupled VERA tools are required to provide the insights and solution to address some of the complex analytical obstacles to power uprates identified in this report. Hence no changes are recommended to CASL with regards to this issue.

6. **ATWS***:* For anticipated transient without scram scenario, the nuclear power plants rely on moderator feedback to survive such transient. ATWS analyses require coupled calculations of 3D kinetics analyses, 3D thermal hydraulics and 3D vessel boron mixing as well as system analysis. The current practice has much room for improvement. For instance point kinetics model is traditionally used. CASL's VERA advanced tools would greatly improve the analysis capability for such issue and no changes are recommended for CASL.

7. The last two issues listed in Table 2 are **Optimized core operating and loading parameters**, and **Vessel fluence and gamma heating**. VERA tools will provide improved predictions for these. No change is recommended to CASL.

2.2 Second Five Year Time Frame

The issues discussed in Section 2.1 are more applicable to Pressurized Water Reactor (PWR). However, there are certain issues CASL will not be able to impact until the 2^{nd} five year time frame (e.g. DNBR correlations/calculations). In addition, there are a set of issues that are specific to Boiling Water Reactors (BWR). CASL will not develop modeling and simulation for Boling Water Reactors until the 2^{nd} five year timeframe. Table 3 shows the obstacles CASL can impact during the 2^{st} five years of its timeframe.

Table 3. Identified Obstacles to Power Uprates and Ability of CASL to Impact during 2^{nd} Five Years

Issue or Obstacle to Power Uprate	**Importance**	**Ability of CASL to Impact**
Power distribution uncertainties (BWR)	High	High
Void coefficient impacts (BWR)	High	High

Applicability of void quality correlations (BWR)	High	High
Bypass voiding (BWR)	High	High
High void neutronics modeling (BWR)	High	High
ATWS (Instability for BWRs)	Med	High
Non-LOCA transients	Med	High
DNBR correlations/calculations	Med	High

1. **Multi-phase flow modeling**: The first five issues listed in Table 3 all have to do with two-phase modeling. Multi-phase flow modeling has been and will remain a grand challenge for modeling and simulation. For instance, CFD modeling for two-phase flow still can not be validated. This is such as important issue for the safety of not only BWRs but also PWRs that it would require significant commitment from CASL. However, so far CASL has not allocated much resource in multi-phase flow modeling.

   Recommendation to CASL: develop a multi-phase flowing modeling strategy and make appropriate investment to address such an important area.

2. **Instability:** Core instability is a unique phenomenon for BWRs and a challenge for the safety of BWR operations. BWR instability is caused by the coupled neutronic and thermal-hydraulic power oscillations that are mainly driven by the negative coolant void feedback with the finite time delay due to the fuel heat conduction. This tends to happen under the lower flow and higher power core operation, corresponding to the density wave oscillation behavior. The BWR core instability can be categorized into the global instability and the regional instability. In the global instability the global core power oscillates in-phase, while in the regional instability the power in a half core oscillates in an out-of-phase mode with respect to the other half. Significant power oscillations may threaten core fuel integrity due to the fuel cladding dryout occurrence and/or due to the strong pellet-clad mechanical interaction (PCMI). Coupled calculations of 3D transient neutronics, 3D thermal hydraulics, fuel performance and pressure waves are important to understand the complicated mechanism of core instability. CASL VERA development in the 2nd five year time frame will be able to address such issue.

   Recommendation to CASL: *add BWR core instability as a challenge problem to the 2nd five year time frame of VERA development.*

3. **Non-LOCA transients**: Coupled calculations of 3D transient neutronics, 3D thermal hydraulics and pressure waves are required to recover the margin loss due to uprated cores. Industry practice has demonstrated the value of limited coupling capability (e.g. RAVE coupling of RETRAN, VIPRE and ANC) to support certain EPU applications. CASL's VERA will provide more advanced tools that are coupled seamlessly through LIME or MOOSE and hence no changes are recommended to CASL.

4. **DNBR correlations/calculations**: DNBR prediction currently uses the empirical correlations developed from the data obtained separate effect experiments conducted in the past. The CASL advanced CFD and multi-phase flow modeling tools will provide more accurate prediction of DNBR without the conservatism built in with the correlations.

2.3 Additional comments on distortion

It was noted at the workshop that this item isn't a direct obstacle to uprates, although fuel distortion must be factored into core performance predictions for an uprated power level. However looking forward, this could become a limiting factor for power uprates. Assembly distortion or bowing could yield less flow across an assembly and reduce heat transfer out of the fuel rods. Previous analyses have shown that assembly distortion could have up to between 6% to 8% impact on power peaking. For BWRs, channel bow prevention has been explicitly incorporated in fuel management and cycle analysis (with safety margin penalized), since shadow corrosion-induced channel bow can cause control blade insertion problems. CASL is very well equipped to address such issue. However, the current plan will not address such issue until much later time.

Recommendation to CASL: consider move fuel assembly distortion issue up in the priority list of the VERA development.

2.4 High importance issues not currently addressed by CASL

A number of issues have high importance to power uprates but are considered somewhat outside the scope of CASL. Table 4 shows those issues. However CASL's advanced tools could impact the resolution of certain aspects of those issues.

Table 4. Issues are important for power uprates, but are not currently addressed by CASL

Issue or Obstacle to Power Uprate	**Importance**
Post-LOCA boric acid precipitation	High
GSI-191	High
Beyond 60 year lifetime extension	High

1. **Post-LOCA boric acid precipitation**: This issue has been around since 1980 or so and it has been getting a lot of attention during NRC reviews of PWR power uprates in the last decade. The PWROG currently has a project to try to respond to the NRC's concerns. The basic concern is that for a cold leg break LOCA in a PWR with a conventional ECCS that pumps into the cold legs or into the vessel downcomer, the elevation of the break will cause most of the ECCS flow to spill out the break after the vessel downcomer has been refilled to the bottom of the cold leg piping ID. The ECCS flow into the reactor for core cooling will equal what is boiled off due to decay heat (and also to a small extent due to heat stored in the vessel structural metal and the fuel). The vessel will be in a "boiling pot" mode, and with the coolant being boric acid this will concentrate the boric acid like an evaporator. Some of the boric acid will be carried with the steam phase out of the vessel, but that is hard to quantify and defend. After being in this boiling pot mode for more than a couple of hours the boric acid concentration will reach the solubility limit and crystals will precipitate and potentially interfere with heat transfer from the fuel rods due to either plating out on surfaces or by blocking the coolant channels. The 10 CFR 50.46 requirement for long-term cooling is the regulation that NRC looks to enforce the designs to mitigate the effects of boric acid precipitation following a LOCA. Note that for a hot leg break the boiling pot mode cannot occur and the phenomenon is not applicable. Plants with unconventional ECCS's may not have this issue or may have unique challenges. There are also differences for the B&W plant design that this document will not get into.

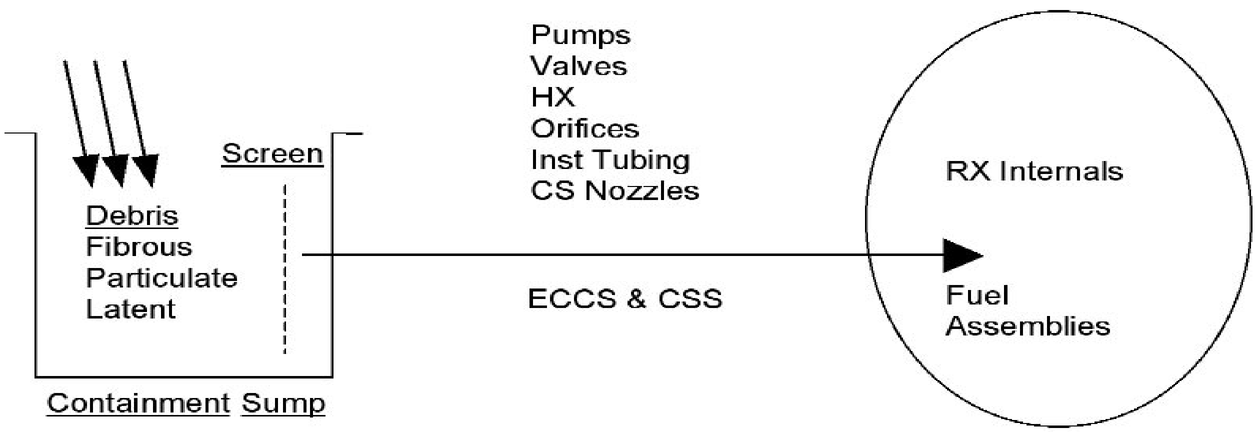
   The PWR fuel vendors or the licensees perform calculations to determine how long the post-LOCA boiling pot mode can be allowed to continue before something must be done to prevent the onset of the precipitation. The NRC has started to review these methodologies and ask questions. Obviously for a power uprate the decay heat is higher and the precipitation will occur earlier. The mitigation strategies are basically of two types. In one strategy the ECCS is realigned to inject through the hot legs to on top of the core. If this flowrate is high enough it will back flush the core and stop the increase in the boric acid concentration before it approaches the solubility limit. The second strategy is to open a hot leg flow path to bleed the concentrated boric acid out of the vessel and stop the increase in the boric acid concentration. Depending on the PWR design these mitigation actions need to occur from roughly 1 to 6 hours after the LOCA. One of the main issues that the industry is facing is that the mitigation strategies were designed for LBLOCA and without regard to SBLOCA, and so they may not work well for SBLOCA.

   Although the focus for the past 30 years has been the large cold leg break LOCA, the NRC is now focused on SBLOCAs that also end up in a boiling pot mode. The NRC has been asking questions related to both LBLOCA and more recently SBLOCA for the last decade or so, and that prompted the PWROG program mentioned above. There is a long and evolving list of NRC questions. For example, they are very concerned that the assumptions about mixing volume are not conservative and the system effects such as time-varied mixing volume due to the variation of the core mixture level and void fraction cannot be addressed in the current boric acid precipitation evaluation. Vendors and licensees have gone to great lengths to defend their assumed mixing volume. The NRC is also interested in the interactions of other chemicals and debris. They are also concerned with crediting higher boric acid solubility due to the temperature of the coolant in the vessel.

Recommendation to CASL: consider a pilot project for such issue to demonstrate the value and capability of CASL's advanced tools.

2. **GSI-191:** The high-energy steam/water jets resulting from a loss of coolant accident (LOCA) or main steam line break may rip away insulation, pulverize concrete, and create other miscellaneous debris particles. Debris generated and transported to the sump has the potential to penetrate the strainers and screens and move to the plant's downstream components located in the emergency core cooling system (ECCS) and containment spray system (CSS). This movement of debris to the ECCS and CSS has the potential to degrade the performance of downstream components. The figure below illustrates this issue.

   Recommendation to CASL: consider a pilot project using CASL's advanced CFD tools to study such issue. .



3. **The Beyond 60 year lifetime extension** issue has to do with the decision the plant owners have to make when they consider the capital investment required for EPUs. If plant owners are assured that their plants will achieve lifetime extension beyond 60 years, they will be more willing to invest large amount of capital investment to refurbish and modernize the plants to support power uprates. CASL's challenge problems include lifetime extension issues on pressure vessel and reactor internals and those would positively impact the lifetime extension decision making. CASL's ability to impact the lifetime extension issue is high. However the current plan does not place much emphasis on this issue.

2.5 Issues outside the CASL scope

There are a few issues identified as having high importance to power uprates, however are outside the scope of CASL and will not be considered by CASL. Table 5 shows those issues.

Table 5. Issues are important for power uprates, but are outside the scope of CASL

Issue or Obstacle to Power Uprate	Importance
Post-LOCA containment pressure	High
Cooling water issues	High

1. **Post-LOCA Containment Pressure**: Containment is one factor that would limit how much uprated power a nuclear power plant can achieve. There are many considerations in containment analyses, such as peak containment pressure and temperature, subcompartment analysis, combustible gas control, containment heat removal (spray and fan cooler), net positive suction head of emergency core cooling system pumps, BWR suppression pool hydrodynamic loads, and BWR drywell bypass. Among these considerations, two concerns stand out with post-LOCA containment pressure. One is that the peak pressure has to stay below the design limit and the other one is that the net positive suction head of the ECCS pumps has to be assured. In terms of assuring peak pressure staying below the design limit, more advanced containment analysis tools are often required to demonstrate the margins at uprated conditions. With regards to assuring NPSH for ECCS pumps, EPUs result in a temperature increase of the sump water in PWRs and the suppression pool water in BWRs during certain postulated accidents or abnormal events. This could affect performance of the emergency core cooling system pumps when taking suction from these water sources. Adequate net positive suction head is necessary for the emergency core cooling system and containment heat removal pumps to deliver flow rate. In some cases, utilities have included containment accident overpressure in their safety analyses to demonstrate acceptable performance of the emergency core cooling system pumps. However, this practice had been questioned by the Advisory Committee on Reactor Safeguards. More mechanistic containment thermal hydraulic codes would better simulate the temperature and pressure behavior in the containments and eliminate the need to take containment accident overpressure credit.

   Recommendation to CASL: For this particular issue, CASL will need to leverage RELAP7 development efforts to demonstrate meaningful impacts.

2. The **cooling water issue** has to do with the adverse environmental impact associated with withdrawing large amount of water from natural water sources to cool the nuclear power plants. This issue is outside the scope of CASL.

3 Conclusion

The issues that have been the largest obstacles for power uprates are largely outside the reactor vessel and in the containment. For example, the post-LOCA containment pressure issue had held up a few BWR EPUs from getting approved. CASL's impact on power uprates in general will be limited to the issues confined within the reactor vessel. A few recommendations can be drawn from this power uprate limit assessment activity with respect to VERA development: 1). Transient analysis capability should be developed for VERA, 2). Multi-scale and multi-phase flow capability is essential for VERA development, 3). Distortion issue should be moved up in the VERA development priority list, 4). Develop an interface strategy between VERA within vessel tools and system analysis tools such as RELAP5 and RELAP7. Table 6 summarizes the results from this power uprate limitation assessment activity.

Table 6. Summary table

	Applicable tools to be developed				
Power Uprate and Associated Modeling Obstacles	**First 5 years**	**Second 5 years**	**Outside of CASL Scope**	**Recommendations**	**Comments**
Coupled code methodology to reduce conservatism	X			None	
Rod ejection, new NRC criteria, 3D analyses and detailed pin census	X (3D pin resolved neutronics only)	X		Ensure that transient capabilities are developed within CASL radiation transport, thermal-hydraulic and fuel rod mechanics codes (target end of second 5 years). Further develop specifications and scope for CASL RIA challenge problem.	Other necessary enhanced code capabilities to address RIA are expected to be developed within CASL's second 5 years, including enhanced DNB predictions, two-phase CFD simulation, and advanced fuel clad modeling (hydriding, ballooning, embrittlement, etc). It is not clear at this time whether the advanced CFD and fuel rod

	Applicable tools to be developed				
Power Uprate and Associated Modeling Obstacles	**First 5 years**	**Second 5 years**	**Outside of CASL Scope**	**Recommendations**	**Comments**
					mechanics codes will support fast transients.
Higher fidelity coupled LOCA transients			X	Add a task to develop an interface strategy between VERA and RELAP. Add a requirement for appropriate RELAP interface points to be included in VERA	LOCA analysis requires a system analysis code which is beyond CASL's currently published first and second five year scope. However CASL is leveraging RELAP5 and RELAP7 development. VERA/RELAP5 interface should be developed in 1st 5 years. VERA/RELAP7 interface will be developed in 2nd 5 years.
24 month cycles (trade off with uprate)	X			Develop fully functional core simulator to establish capability to perform reactor cycle calculations and ability to evaluate design and safety margins.	The core simulator should not require HPC and with reasonable run times.
Numerical methods and computation time	X			None	Computation time is expected to be longer than current industry codes due to

	Applicable tools to be developed				
Power Uprate and Associated Modeling Obstacles	**First 5 years**	**Second 5 years**	**Outside of CASL Scope**	**Recommendations**	**Comments**
					higher fidelity 3D approach.
ATWS	X (PWR)	X (BWR)		None	
Multi-phase flow modeling		X		A CASL strategy for multi-phase flow modeling is required	
BWR Core Instability		X		Add as a second 5 year challenge problem.	
Non-LOCA transients		X		None	
DNBR Correlation & Calculations		X		None	
Assembly Distortion	X			Move fuel assembly distortion issue up in the priority list of the VERA development.	Structural mechanics capability is needed.
Post-LOCA boric acid precipitation		X		Add as a second 5 year challenge problem.	CRUD deposition tools could be adapted to simulate.
GSI-191	X			Consider a pilot project using CASL's advanced CFD tools to study such issue.	Particle tracking and transport not included.
Post-LOCA Containment Pressure:			X	Incorporate sufficient materials and structural models to allow simulation.	A parametric study could be completed with VERA but would need to be put in

	Applicable tools to be developed				
Power Uprate and Associated Modeling Obstacles	**First 5 years**	**Second 5 years**	**Outside of CASL Scope**	**Recommendations**	**Comments**
					context by other programs such as LWRS.
Beyond 60 year lifetime extension		X		None	This is a stated goal of CASL. Since there is currently little effort dedicated to this goal, it is placed in the 2nd five year time frame.
Cooling Water			X	None	

Appendix A: Input from FAs on their respective ability to impact power uprates

Issues/Obstacles to Power Uprate	Importance (High, Med, Low)	Ability of CASL to Impact (High, Med, Low) AMA	MPO	THM	RTM	VRI	VUQ
Applicability of void quality correlations	High	Medium (5year+ due to 2 phase flow)		High 5 yr+			High 5 yr+
Bypass voiding	High	Medium (5year+ due to 2 phase flow)		High 5 yr+			High 5 yr+
Coupled-code methodology to reduce conservatism	High	High		High	High	High	Verification medium
GSI-191	High	High (not modeling particulates)		Med 5 yr+			High Sensitivity & UQ
High void neutronics modeling	High	Medium (5year+ due to 2 phase flow)			High 5 yr+		High 5 yr+
Void coefficient impacts	High	Medium (5year+ due to 2 phase flow)			High 5 yr+		High5 yr+
Containment pressure in post-LOCA	High	Low		Low			low
	High	Low					low

Issues/Obstacles to Power Uprate	Importance (High, Med, Low)	Ability of CASL to Impact (High, Med, Low) AMA	MPO	THM	RTM	VRI	VUQ
Cooling water issues with power uprates							
Annulus pressurization loads on BWR core shrouds, piping and pumps vibration, and flow induced jet pump vibrations	Medium	High		Low			High
Optimized core operating and loading parameters	Medium	High			High		High
Vessel fluence and gamma heating	Medium	High			High		Medium
DNBR correlations/calculations	Medium	Medium		High 5 yr+			HIGH
Numerical methods and computation time	Medium	Medium		High	High	High (automated coupling and parallel processing)	HIGH
Spent fuel pool criticality margins	Medium	Medium			Med		MEDIUM
Beyond 60 year lifetime extension	High	Medium	med				
Post-LOCA boric acid	High	High	high	Med			HIGH

Issues/Obstacles to Power Uprate	Importance (High, Med, Low)	Ability of CASL to Impact (High, Med, Low) AMA	MPO	THM	RTM	VRI	VUQ
precipitation				5yr +			
Higher fidelity coupled LOCA transients	High	High (5 year+)	high	High 5 yr+		High 5 yr+	HIGH
Power distribution uncertainties (BWR)	High	Medium (5year+ due to 2 phase flow)	high		High 5 yr+		HIGH 5 YR+
Rod ejection, new NRC criteria, 3D analyses and detailed pin census	High	High	high		High	Med	HIGH
24 month cycles (trade off with uprate) fuel reliability margins (higher power fuel/higher density fuel/higher burnup fuel core loading studies)[1]	High	High	high		High 5 yr+	Depends on priority placed on ease and speed of simulation	HIGH
ATWS (instability for BWRs)	High BWRs Medium PWR	Low	low	High 5 yr+	High 5 yr+	High 5 yr +	HIGH 5 +

[1] It was noted at the workshop that this item isn't a direct obstacle to uprates; however, 24-month cycles are highly desirable and currently they are considered to be incompatible with uprated Westinghouse 4-loop plants.

Issues/Obstacles to Power Uprate	Importance (High, Med, Low)	Ability of CASL to Impact (High, Med, Low) AMA	MPO	THM	RTM	VRI	VUQ
Distortion (rod and assembly bow)[2]	Medium	High	high			Ability to impact is high, current plan is low	MEDIUM
Increased irradiation-assisted stress corrosion cracking of core internals	Medium	High	med				MEDIUM
Non-LOCA transients	Medium	High	med	Med			HIGH
Reactor internals structural – steam dryers (BWR), core plates, baffles, BWR core shrouds	Medium	High	med				MEDIUM
Seismic and LOCA loads	Medium	Medium	med				MEDIUM
Centerline Fuel Melt calculations	Low	High	high				HIGH
Steam generator tube rupture single failure analysis	Low	Low	low	Med 5 yr+			MEDIUM
Flow-accelerated	Low PWR	Low	high	Hgih 5			HIGH

[2] It was noted at the workshop that this item isn't a direct obstacle to uprates, although fuel distortion must be factored into core performance predictions for an uprated power level.

Issues/Obstacles to Power Uprate	Importance (High, Med, Low)	Ability of CASL to Impact (High, Med, Low) AMA	MPO	THM	RTM	VRI	VUQ
corrosion (BOP)	??? BWR			yr+			