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Consideration of External Hazards and Multi-Source Interactions in the USNRC's Site Level 3 PSA Project

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Outline

- Level 3 PRA project overview
- External hazards analysis approach
- Current thoughts: Integrated Site Risk Analysis (ISRA)
- Concluding remarks

Level 3 PRA Project – Objectives

- Develop a Level 3 PRA, generally based on current state of practice methods, tools, and data,* that (1) reflects technical advances since completion of the NUREG-1150 studies, and (2) addresses scope considerations that were not previously considered (e.g., multi-unit risk)
- Extract new insights to enhance regulatory decisionmaking and to help focus limited agency resources on issues most directly related to the agency's mission to protect public health and safety
- Enhance NRC staff's PRA capability and expertise and improve documentation practices to make PRA information more accessible, retrievable, and understandable
- Obtain insight into the technical feasibility and cost of developing new Level 3 PRAs

* "State-of-practice" methods, tools, and data are those that are routinely used by the NRC and licensees or have acceptance in the PRA technical community.

Technical Analysis Approach Plan

- Objective: To provide the guidance to be used in developing the Level 3 PRA.
  - Consistent with current best practice as defined in both national consensus standards and other regulatory and industry guidance documents
  - Enhance consistency in the development of the PRA models by the various analysts
  - Provide traceability of how the PRA model was constructed
  - Used to support development of review criteria for assessing the technical acceptability of the PRA model
- This PRA model is comprised of the following scope:
  - Radiological sources -- reactor cores, spent fuel pool, and dry cask storage
  - Impact population -- surrounding population
  - Reactor state -- all operating states
  - Challenges -- all hazards
  - Levels of risk analyzed -- Levels 1, 2 and 3

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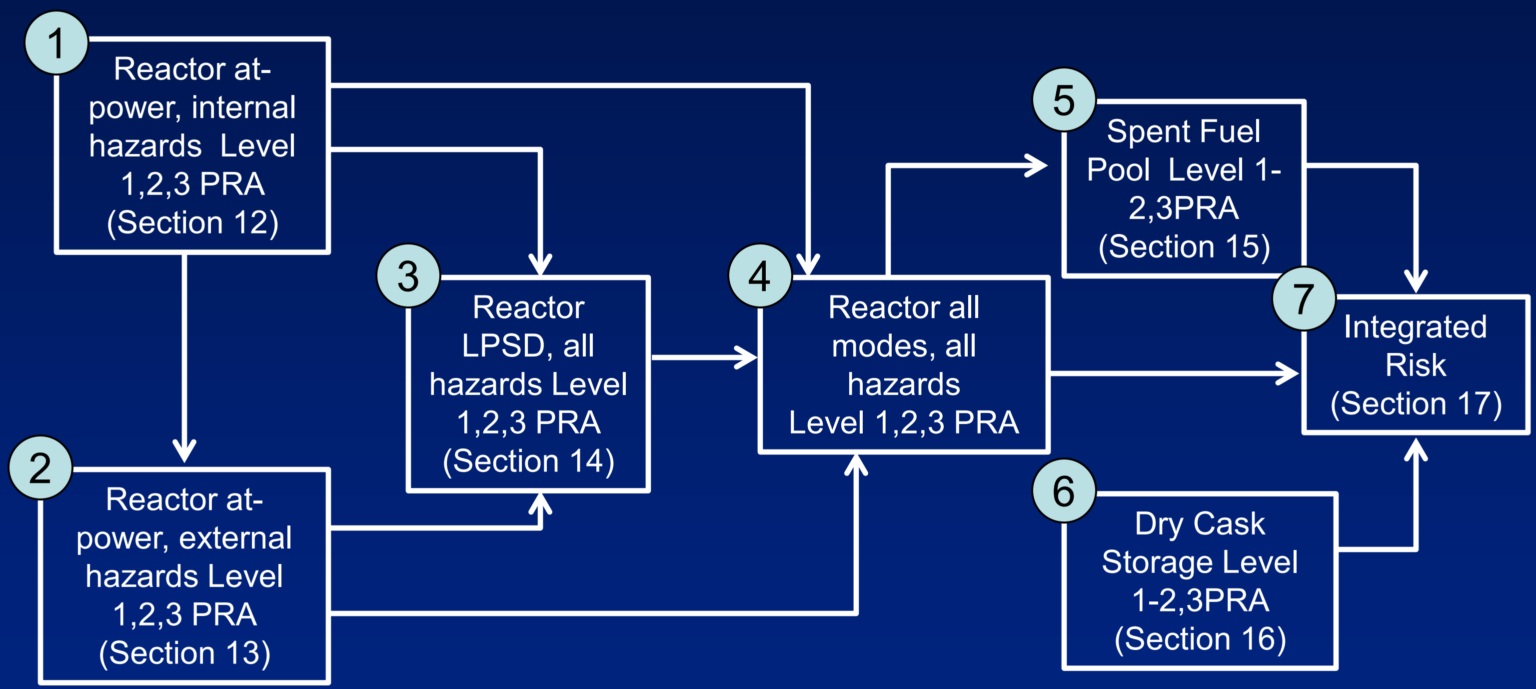
Approach Summary



Selected Approach

- Produces reactor Level 3 results before completing entire site study
- Provides additional time to resolve technical issues in less mature areas

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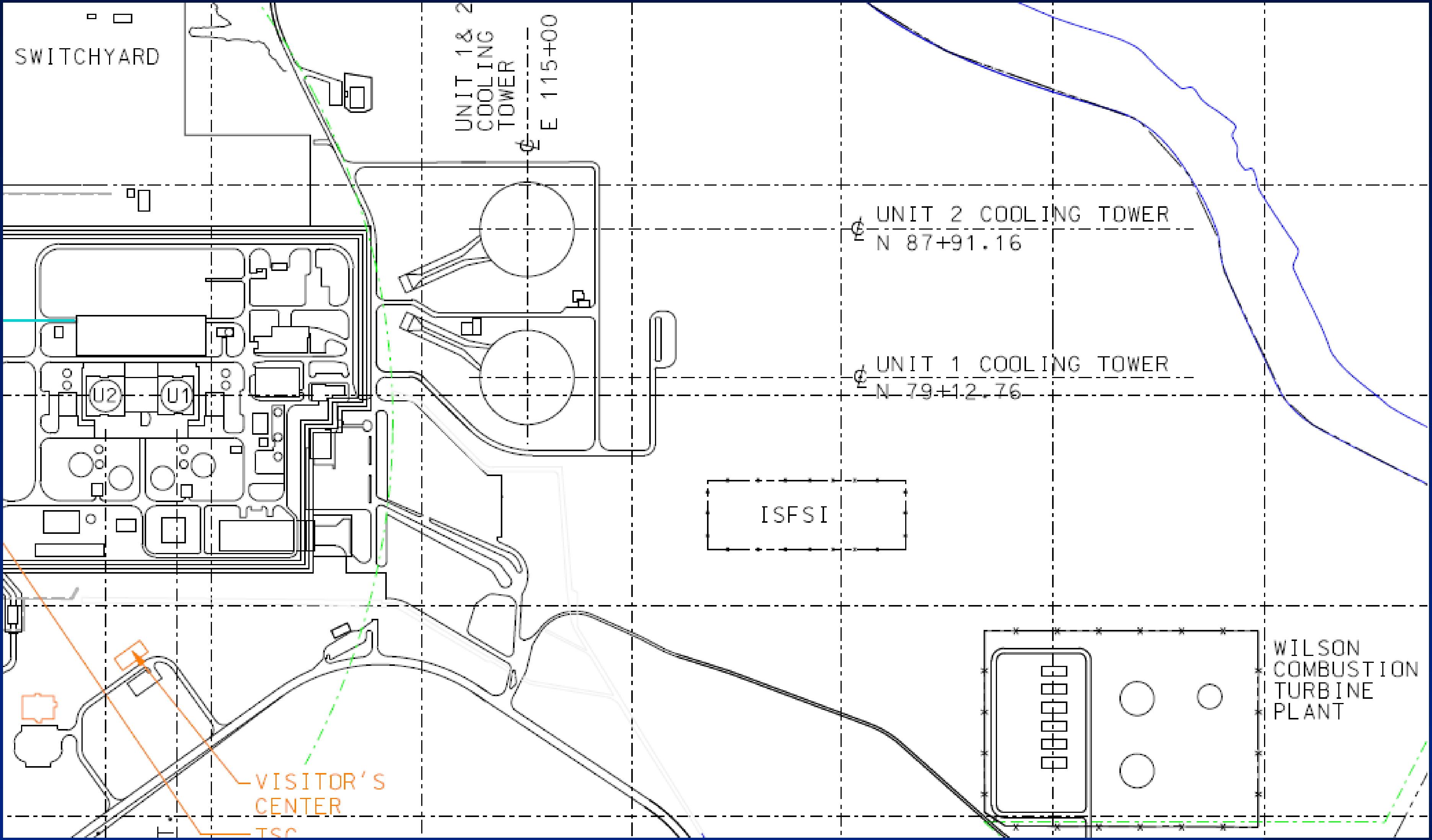
Vogtle Site Layout



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Sesimic PSA – Background

- The licensee is in the process of performing a seismic PRA.
- The NRC's Level 3 PRA model will leverage available information and calculations from the licensee's seismic PRA.
- ASME/ANS PRA Standard Section 5-2 identifies the technical requirements for a seismic PRA at-power.
  - Probabilistic seismic hazard analysis
  - Seismic fragility evaluation
  - Seismic plant response analysis
- Mix of in-house (RES staff) and contracted effort will be used.

SPSA – Challenges

- Characterization of ground motion at the site using recent probabilistic seismic hazard models
- Changes in spectral characteristics of ground motion and site conditions challenge scaling of FSAR's in-structure spectral acceleration demands on SSCs
- Soil site with local site amplification effects that affect ground motion characteristics and related seismic hazard quantification
- Consideration of soil-structure interaction effects on calculation of in-structure spectral acceleration demands on SSCs
- Consideration of potential for site-specific soil failures, e.g., soil liquefaction

Other External Events – Background

- The licensee has not performed a PRA for high winds, external floods, or other events.
- Collective experience with detailed PRA modeling of these events is limited.
- ASME/ANS PRA standard Sections 7.2, 8.2, and 9.2 provide the technical elements for addressing these events.
- A mix of in-house (RES staff) and contracted effort will be used.

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Other EE – Assumptions and Limitations

- The analysis for these events may be qualitative, quantitative, or a combination of each, as warranted by the site-specific hazard characteristics.
- The high wind analysis is expected to be quantitative, leading to scenarios to be incorporated into the PRA model.
- The external flooding analysis is not expected to require a detailed quantitative PRA model.
- The other events under consideration will consist of the hazards listed in Appendix 6-A of the ASME/ANS RA-Sa-2009 PRA standard.

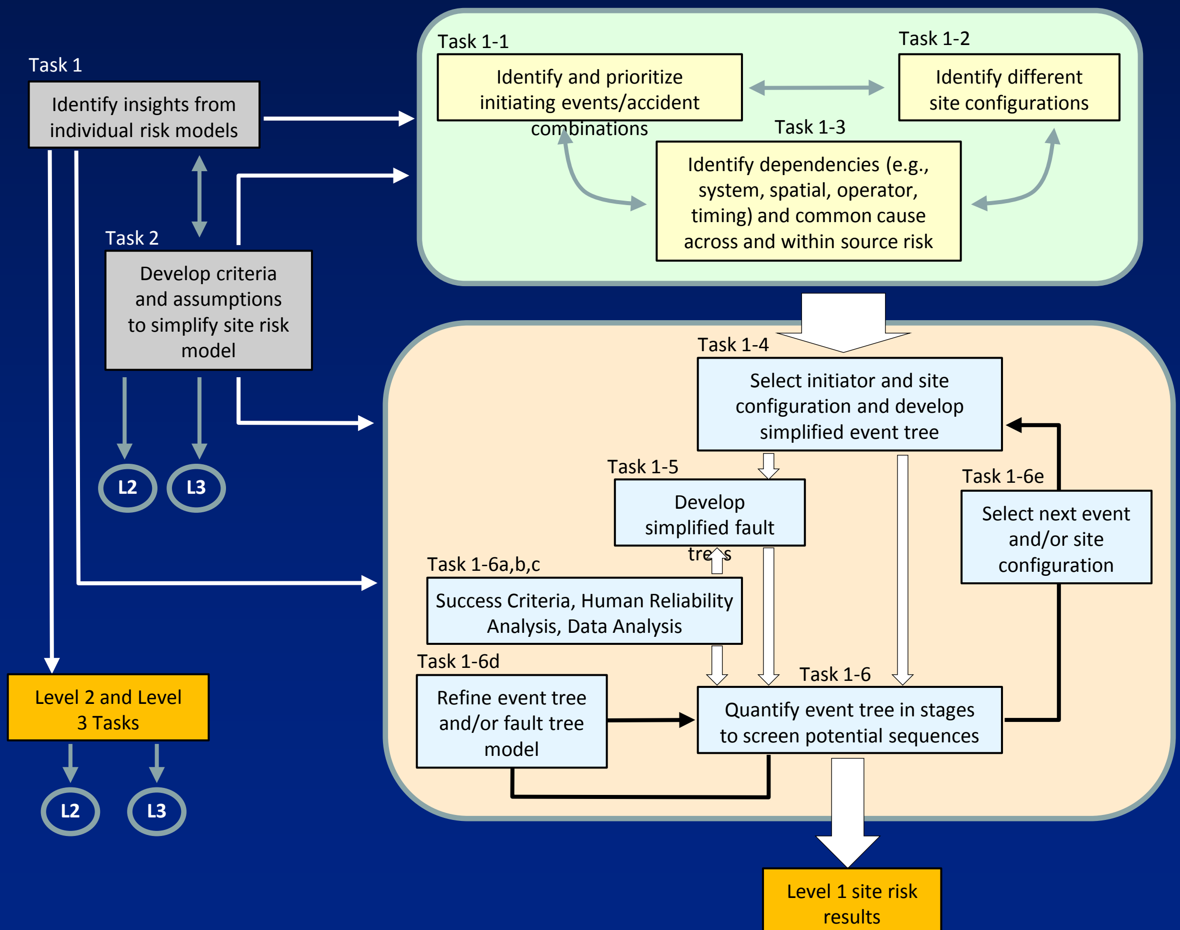
ISRA – Preliminaries

- Assumption: multi-source accident sequences can be formed by combining sequences from the single-source PRA models.
- The ISRA will focus on identifying and analyzing risk-significant multi-source risk contributors.
  - Emphasis is on project breadth
  - Quantification challenge (many, many sequences!)
  - Need to use simplified logic models
- The ISRA is a highly iterative effort.

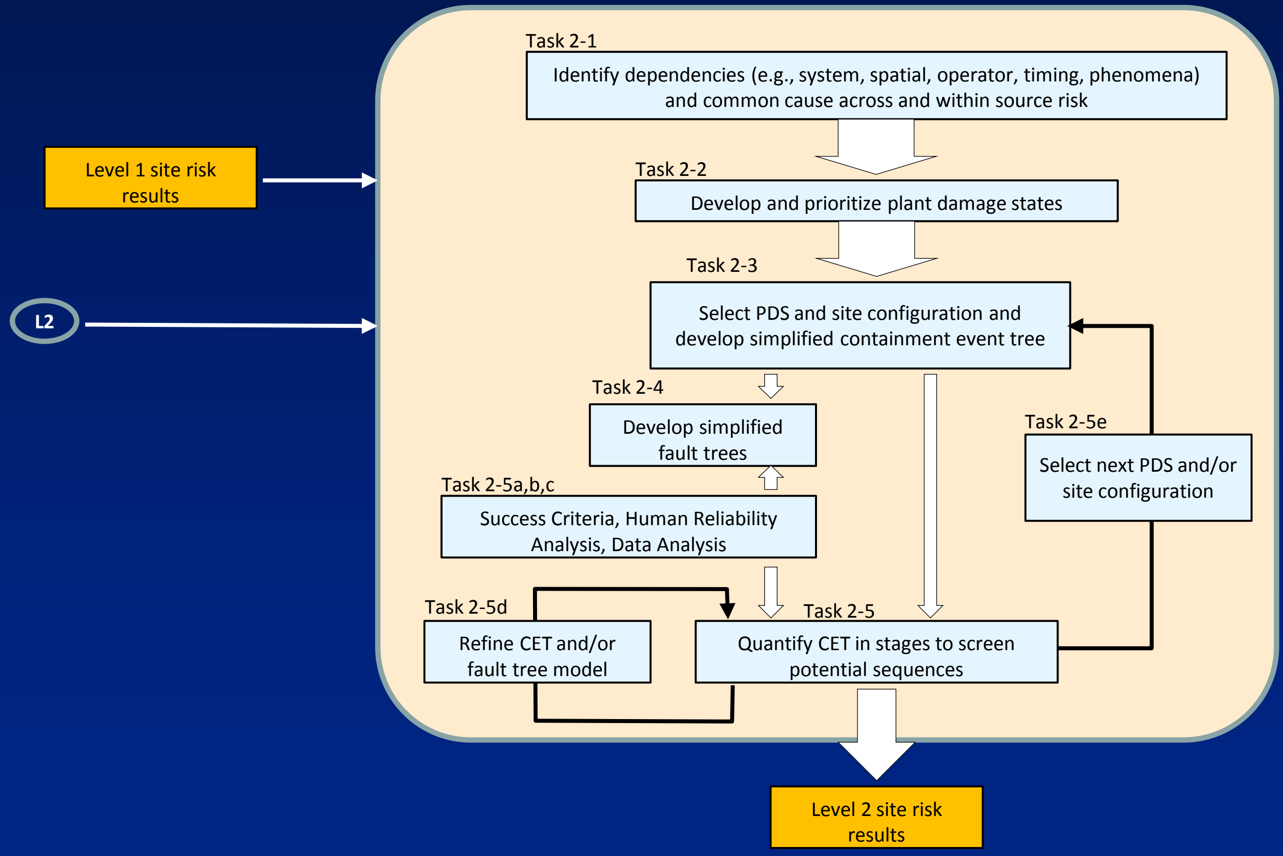
Initiating Event Classes

- Single-source initiators (SSIs): Initiators that occur in one source.
  - SSIs generally include initiators caused by internal hazards
    - Internal events (e.g., loss of main feedwater, loss-of-offsite-power events, and loss-of-coolant accidents)
    - Internal floods
    - Internal fires.
  - SSIs may cause multi-unit accidents due to cross-unit dependencies such as shared support systems, spatial interactions (e.g., flood propagation pathways), common-cause failures, or operator actions.
  - Restricted, cascading, and propagating sequences
  - Each initiator for each source must be considered
- Common-cause initiators (CCIs): Initiators that simultaneously challenge all of the units at a multi-unit site.
  - CCIs include initiators caused by external hazards
  - Earthquakes
  - External floods
  - Severe weather

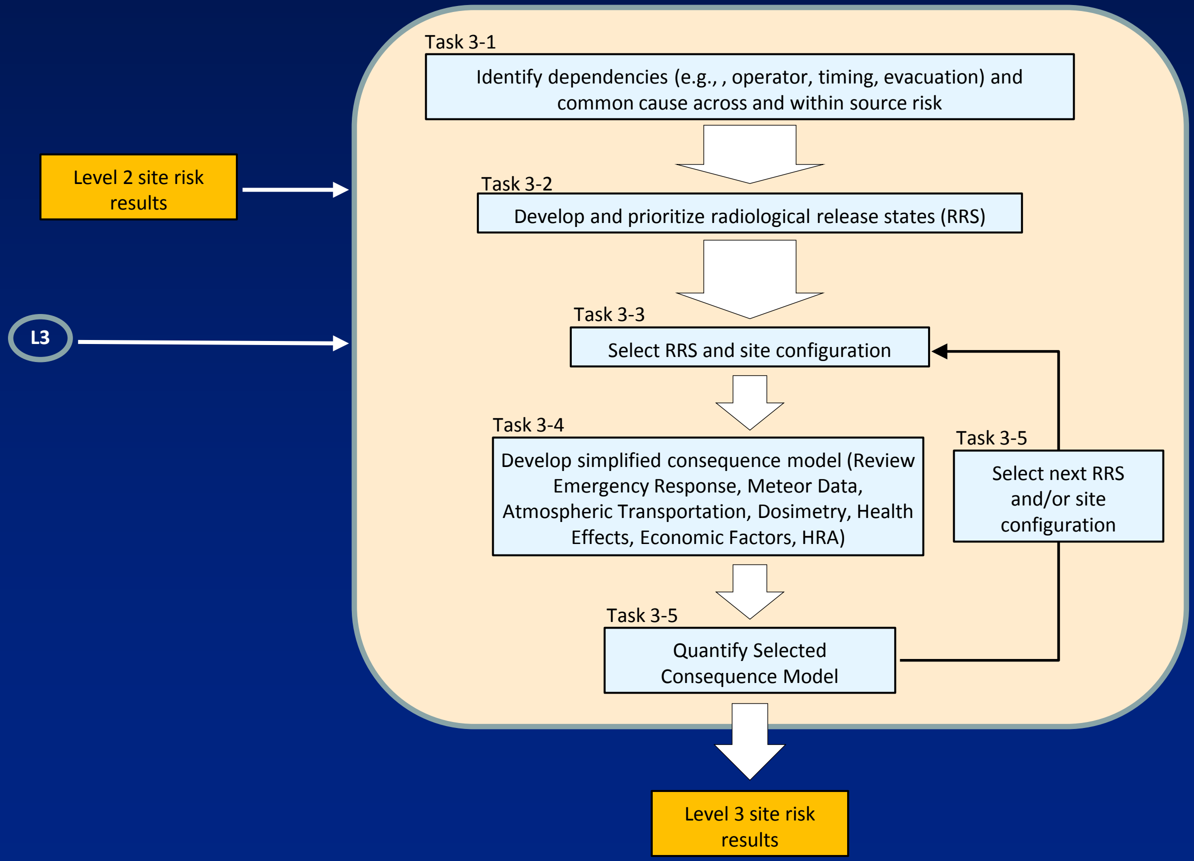
ISRA Flowchart (Level 1)



ISRA Flowchart (Level 2)



ISRA Flowchart (Level 3)



Screening and Scoping Strategies

- Use risk insights from each single-source PRA to focus attention on risk-significant multi-source accidents.
- Possible strategies:
  - Screening on the likelihood of the specific site configuration.
  - Screening on the partial multi-source sequence frequency.
  - Screening on the partial multi-source sequence risk.

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ISRA EE Modeling Challenges (1 of 2)

Multiple sources + long duration scenarios =>

- Combinatorial Explosion
  - Screening
  - Searching
- Potential Analysis Heterogeneity
- Hazard Analysis Complexities
  - Coupled, multiple hazards (including aftershocks)
  - Persistence
  - Dynamic loads

ISRA EE Modeling Challenges (2 of 2)

- Fragility Analysis Complexities
  - Additional SSCs (e.g., access control)
  - Weakening
- Systems Analysis Complexities
  - Effects on operators
  - Treatment of SAM (including organizations)
  - Warning time
- Offsite modeling
  - Dynamic response
  - Multiple plumes

ISRA – Other Challenges

- Computation
- Communication (metrics)*

Risk Metric	QHO	Reported in NUREG-1150	Regulatory Analyses
Total early fatality risk		X	
Total latent cancer fatality risk		X	
Individual early fatality risk (0-1 miles)	X	X	
Individual latent cancer fatality risk (0-10 miles)	X	X	
Population dose risk (person-rem/y)		X	X
Offsite economic cost risk			X

  – Cancer incident risk?
  – Land contamination risk?

*Under discussion

Possible WGRISK Follow-Ons?

WGRISK Mission

"Provide a forum for information exchange that advances the understanding and utilisation of probabilistic safety assessment (PSA), thereby supporting the CSNI as it assists member countries in ensuring the safety of existing and future nuclear installations."

- An electronic dialog on technical challenges?
  - List of challenges
  - "Crowdsourcing" and/or Wiki for potential solutions/lessons
- Discussions on risk metrics and site-level risk surrogates?

BACKUP SLIDES

SPSA – General Approach

- Use existing site-specific seismic hazard information to define seismic bins
- Customize the seismic demands on the structures, systems, and components (SSCs) to the actual site using approximate methods and existing information (FSAR and ongoing seismic PRA study) and will update those results as more information becomes available
  - Perform sensitivity analysis to assess bounding effects of approximations
- Use available site-specific seismic fragilities to calculate basic event failure probabilities for seismic bins
  - Perform in-house fragility calculations or use surrogate fragilities, where necessary

SPSA – General Approach (cont.)

- Develop event tree and fault tree models for each seismic bin
  - Use existing event tree and fault tree models from internal events PRA, wherever applicable
- Assemble new data to be put in the model (including uncertainty parameters)
  - Hazard bin frequencies, seismic failure probabilities, new or affected human error probabilities, and other data
- Incorporate scenarios into Level 3 PRA model and quantify core damage frequency

SPSA – Assumptions and Limitations

- Licensee will be working on a seismic PRA in the same time frame as this project. The NRC's Level 3 PRA model will leverage information and calculations from the licensee's seismic PRA, as available and appropriate.
- A stable version of the internal events model will be available before the seismic scenario modeling task starts.

Other EE – General Approach

- The general tasks for high-winds and external flood PRA include:
  - Hazard analysis
  - Fragility analysis
  - Plant response analysis, including quantification
- The general tasks for the other events include:
  - Review of plant-specific hazard data and licensing bases
  - Screening analyses
  - Modeling of unscreened hazards

Project Status (1 of 3)

- Level 1, at-power, internal events model nearing completion
  - Some work remains on human reliability analysis (HRA) and data
  - Completed internal self-assessment (documentation is almost complete; some clarifications needed from licensee; currently excludes HRA)
- Level 1, at-power, internal floods model progressing
  - Need to update flood frequencies and perform walkdown
  - Will perform self-assessment shortly
- Level 1, at-power, fire, seismic, and other external hazards recently begun
  - Walked down Vogtle site and Unit 2 containment; visited SNC headquarters
  - Progressing with fire scenario mapping and integration
  - Beginning seismic modeling (based on licensee information and staff analyses)
  - Schedule pushed back a few months due to budget limitations and delays in receiving plant information

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Project Status (2 of 3)

- Level 1, low power and shutdown modeling is just beginning to ramp up (biggest challenge will be fires and external hazards)
- Level 2, at-power, internal events model progressing
  - Completed SCALE analysis for reactor and spent fuel pool
  - Completed MELCOR model for Unit 1 reactor and containment
  - Completed finite element model of one Vogtle containment
  - Walked down Vogtle auxiliary and fuel handling buildings, and Unit 2 containment
  - Main challenges are funding, SAPHIRE capabilities, HRA, staff availability
- Level 3 (consequence analysis) work is progressing
  - MACCS2 development focused on improved emergency preparedness (EP) model capabilities, better support for multisource releases, and updated population and economic databases
  - EP team will visit site and surrounding areas in June 2013
  - Main challenges are funding, staff availability, and information availability

Project Status (3 of 3)

- Spent fuel pool modeling is progressing (main challenges are staff availability, HRA, offsite mitigation)
- Dry cask storage is progressing (main challenge is information availability)
- Integrated site risk is progressing
  - April 2013 workshop
  - TAAP section prepared
  - Scoping approach being developed
- Dialogue begun with PWROG regarding external peer reviews

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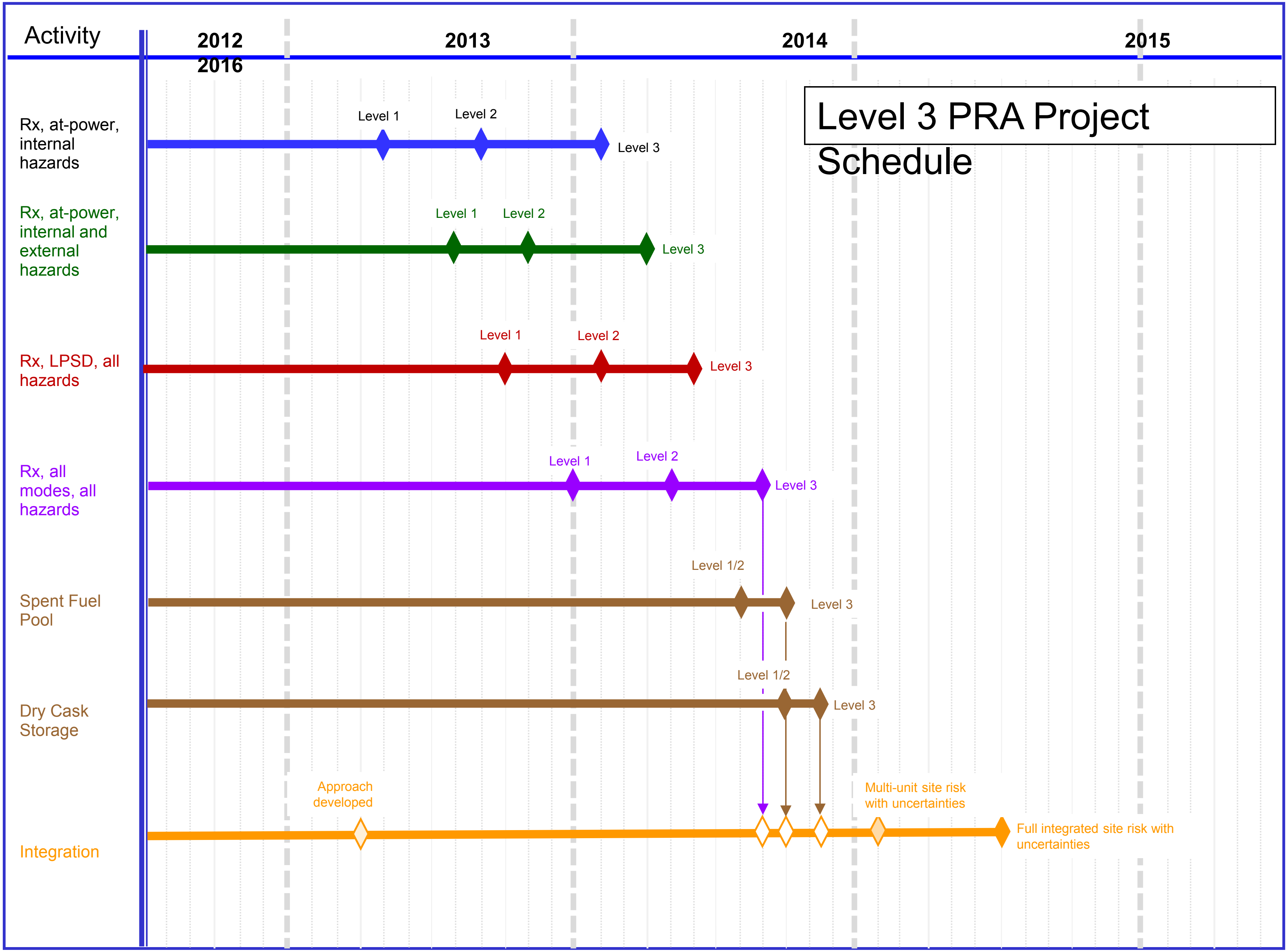
Upcoming Briefings

- ACRS PRA Subcommittee: approach for addressing integrated site risk and results of Level 1 PRA, at-power, internal events and floods self-assessment (July 2013)
- ACRS PRA Subcommittee: preliminary results (October 2013)
- ACRS Full Committee: project status and preliminary results (December 2013)


Level 3 PRA Project Schedule
Activity
2012
2016
2013
2014
2015
Rx, at-power, internal hazards
Level 1
Level 2
Level 3
Rx, at-power, internal and external hazards
Level 1
Level 2
Level 3
Rx, LPSD, all hazards
Level 1
Level 2
Level 3
Rx, all modes, all hazards
Level 1
Level 2
Level 3
Spent Fuel Pool
Level 1/2
Level 3
Dry Cask Storage
Level 1/2
Level 3
Integration
Approach developed
Multi-unit site risk with uncertainties
Full integrated site risk with uncertainties