nuclear power generation

B&W mPower™ Reactor Design Certification Pre-Application Meeting

October 27, 2009

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Meeting Agenda

TIME	TOPIC	LEAD
10:00 a.m. – 10:10 a.m.	Introduction and opening remarks	NRC/B&W
10:10 a.m. – 10:40 a.m.	Overview of mPower design	J. Halfinger
10:40 a.m. – 10:50 a.m.	mPower project schedule	T.J. Kim
10:50 a.m. – 11:30 a.m.	Human Factors Issues	J. DeBor
11:30 a.m. – 11:40 a.m.	NRC feedback & next steps	All
11:40 a.m. -- 11:45 a.m.	Opportunity for public comment	Public
11:45 a.m.	Adjourn open meeting	
11:45 a.m. – 12:30 p.m.	Lunch	

[The following discussions will NOT be open to the public.]

1:00 p.m. – 1:45 p.m.	Design Verification Test Plan	D. Lee
1:45 p.m. – 2:15 p.m.	Compliance with GDCs	S. Hobbs
2:15 p.m. – 2:30 p.m.	NRC Feedback & Next Steps	All
2:30 p.m.	Adjourn	

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nuclear power generation

Introduction to the B&W mPower™ Design

B&W Nuclear Power Generation Group

October 27, 2009

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B&W *mPower*™ Design Update

- Overall Design Approach
- Integral Nuclear Steam Supply System (NSSS)
  - Design Characteristics
  - Core & Fuel Assemblies
- Safety Philosophy
- Containment
- Balance of Plant Overview
- Summary

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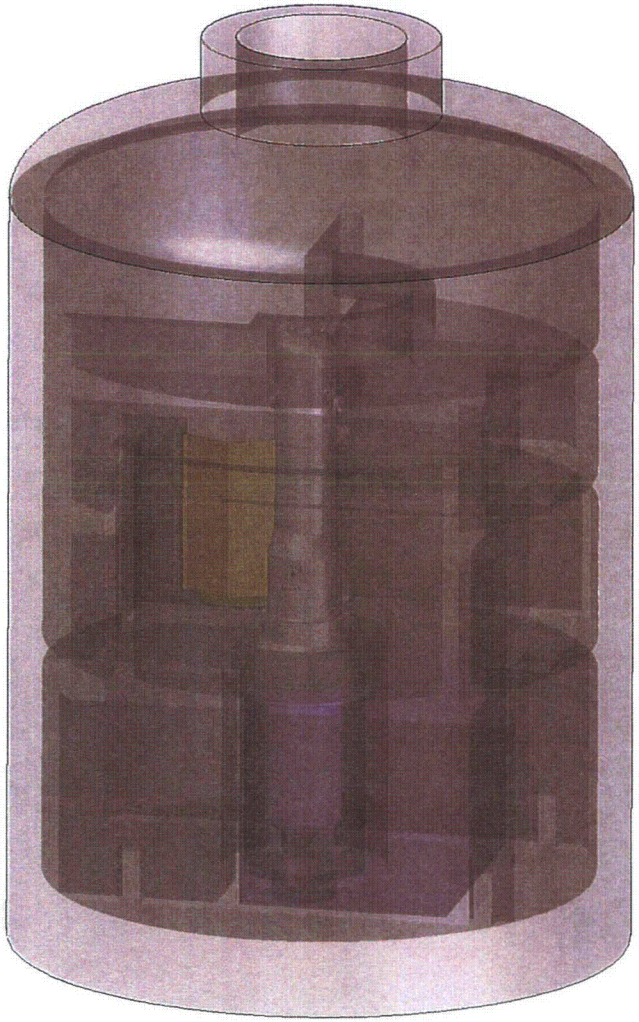
B&W *mPower* Overall Design Approach



- 425 MW_{th} Integral NSSS based on B&W Consolidated Nuclear Steam Generator Program PWR experience
- Standard PWR fuel assemblies
- Passive decay heat removal system
- Reactor Containment Building housing the NSSS, the high pressure reactor coolant purification system, and spent fuel storage
- No soluble poison used in normal operation
- Control rods used for reactivity control
- No Class 1E emergency diesel generators
- Traditional turbine-generator and Balance of Plant (~125 MWe)

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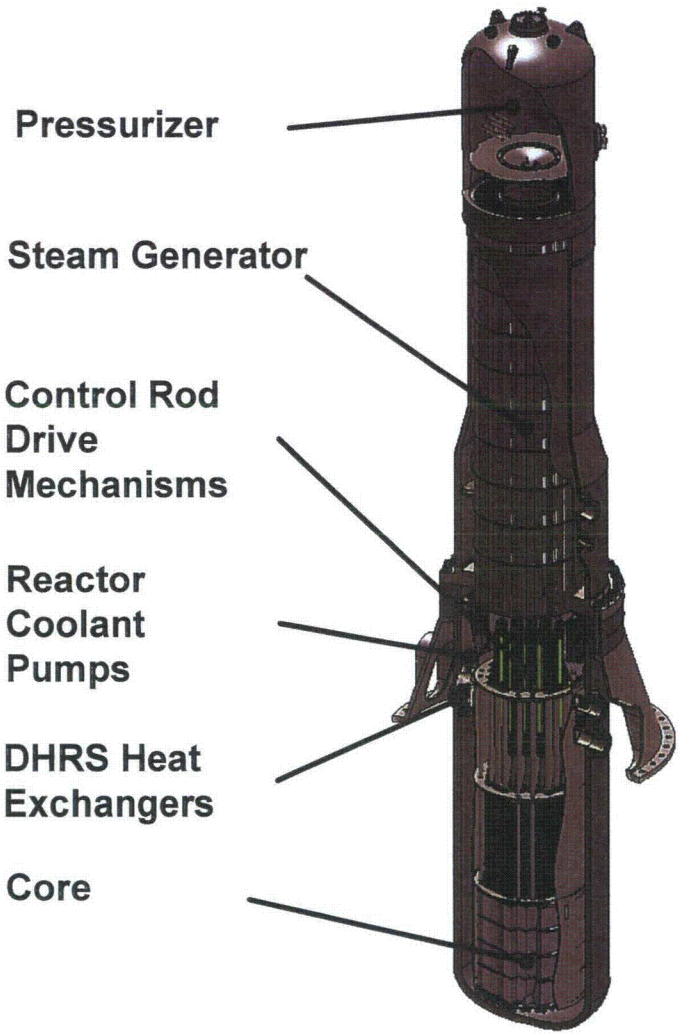
Integral Nuclear Steam Supply System



- Integrates core, steam generator, and pressurizer into a single vessel
- Control rod drive mechanisms (CRDMs) and primary coolant pumps inside vessel
- Decay heat removal system (DHRS) heat exchangers inside pressure vessel
- Reactor coolant pressure boundary penetration size and location minimize coolant loss during loss of coolant accident (LOCA)
- Core remains covered throughout design basis LOCA

Integral design reduces complexity and enhances safety

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Design Characteristics

Design Characteristic	Value
Reactor Type	PWR
Thermal Power	425 MW
Reactor Coolant	Light Water < 14 MPa (2000 psia) ~595°K (609°F) Core outlet
Steam Conditions	< 7 MPa (1000 psia) Superheated
Reactor Vessel	Diameter ~ 3.6 m (12 feet) Height ~23 m (76 feet)
Fuel Assemblies	69 - 17x17 fuel assemblies Height ~1/2 of Standard FA

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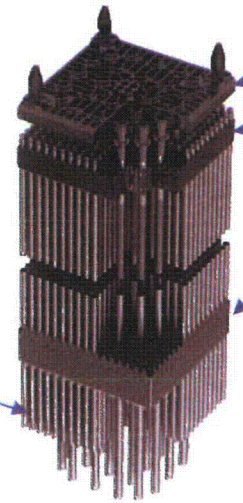
Fuel Assembly Characteristics

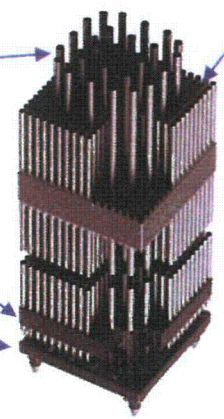


Top nozzle

Top spacer grid

Intermediate spacer grid

17 x 17 fuel rod array



Control rod guide thimble

Fuel rod

- **Low power density**
- **Corrosion resistant Zircaloy**
- **Large plenum volume**

Bottom spacer grid

Bottom nozzle

Top end plug

Upper plenum

Clip

Top spacer

Fuel pellet column

Bottom spacer

Standoff

Bottom end plug

Shortened and Simplified Conventional Fuel Assembly Design

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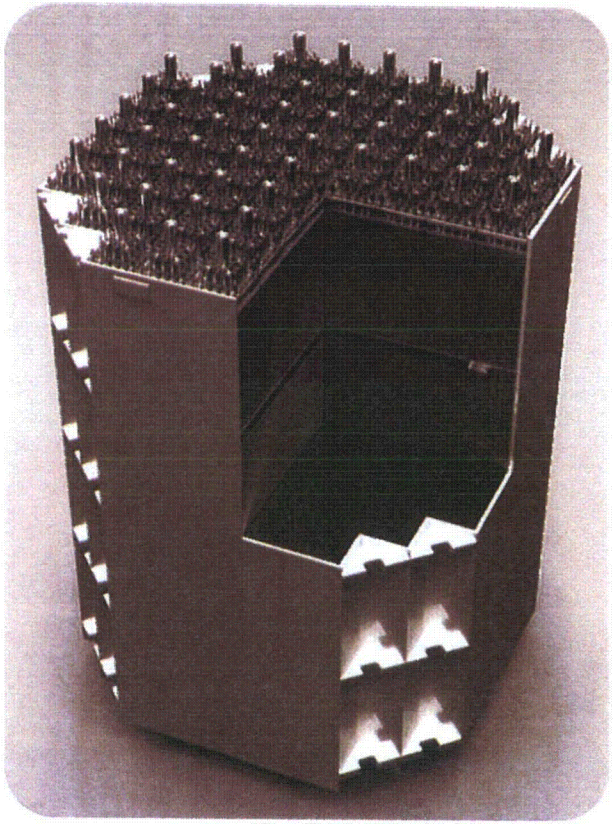
Reactor Core Characteristics

Reactor Core Parameters	
Number of Fuel Assemblies	69
Fuel Assembly Pitch	21.5 cm
Active Core Height	~ 200 cm
Core Diameter (Flat-To-Flat)	~ 200 cm
Fuel Inventory	< 20 MT
Average Specific Power	~20 kW/kgU
Core Average Fuel Burnup	<40 GWd/MTU
Target Fuel Cycle Length	~ 5 yrs
Maximum Enrichment	< 5%



Conventional Core Design with Low Power Density

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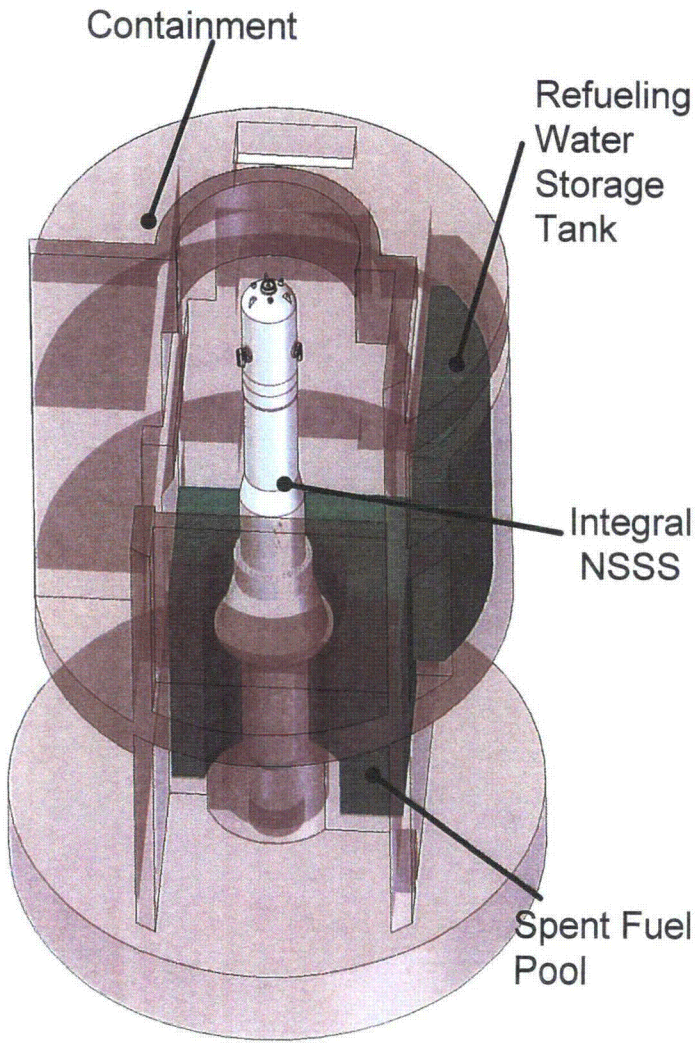
B&W *mPower* Design Safety Philosophy

- Conventional defense in depth for fission product release
- Inherent design features preclude need for active engineered safeguards
  - Passive core and containment cooling
  - No large-break LOCA
  - No RCS penetrations below top of core
  - Large coolant inventory (*Core remains covered in design basis LOCA)*
- Maximize containment of radioactive materials
  - RCS purification system piping inside containment
  - Spent fuel stored inside containment
  - Below-grade containment



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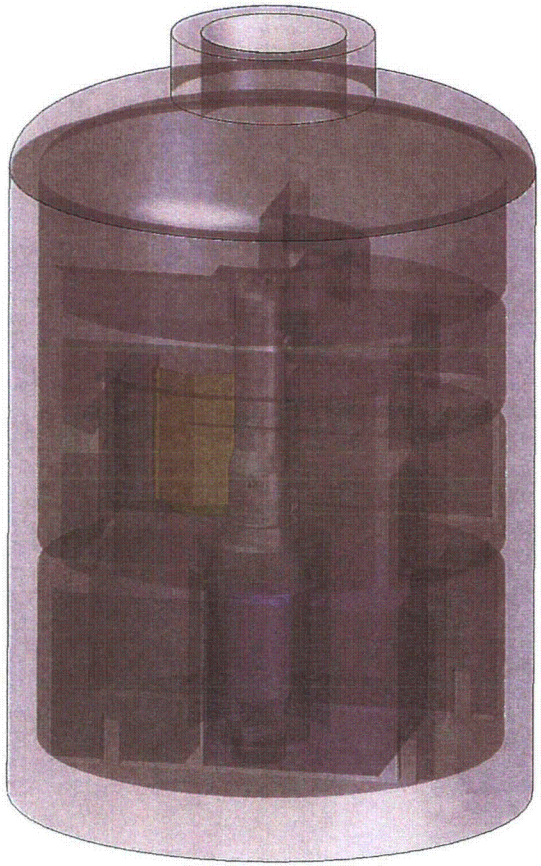
Containment



- NSSS and all high-energy pipe containing reactor coolant is located within containment
- Spent fuel stored inside containment
- Containment provides sufficient thermal storage to reduce peak pressure after LOCA by >50% within 24 hours

Provides traditional defense in depth to minimize release of radioactive materials

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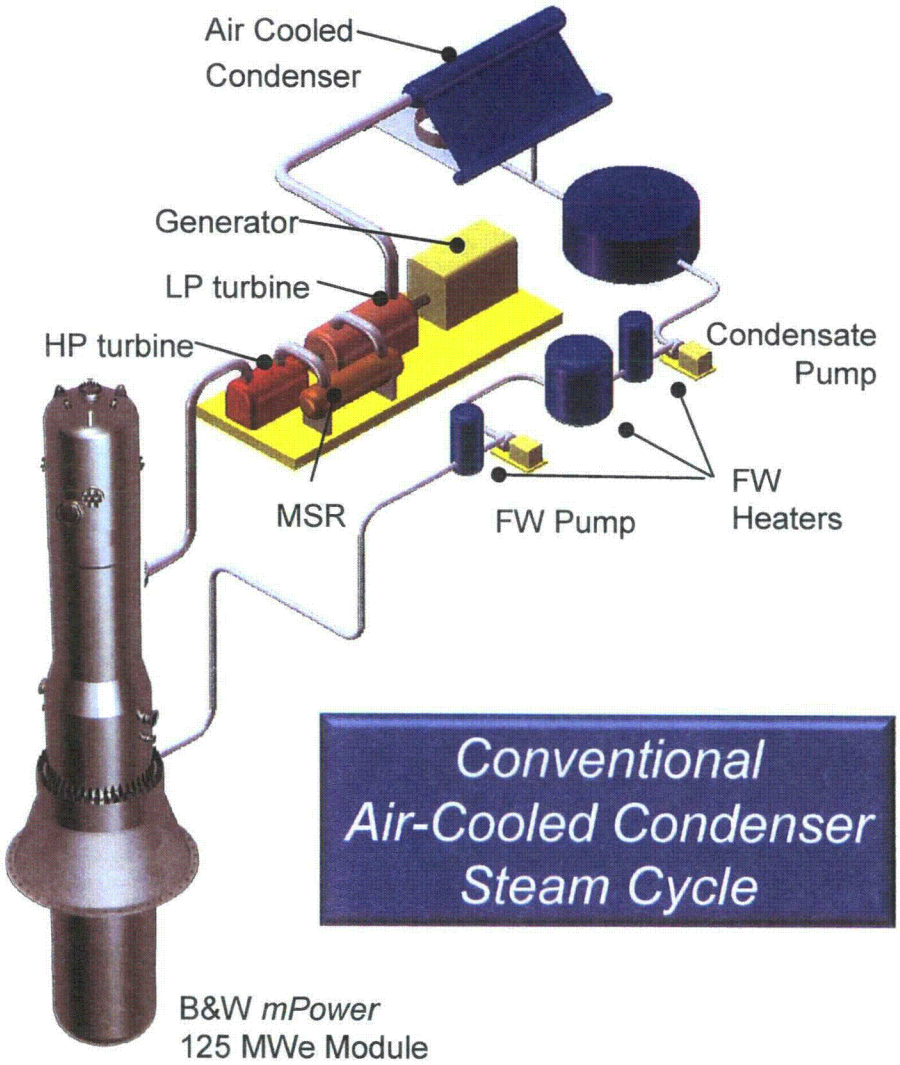
Balance of Plant Design

- Plant designed to produce a nominal 125 MWe gross
  - Air-cooled condenser (Baseline)
  - Water-cooled condenser
- Conventional steam cycle equipment
- BOP operation not credited for design basis accidents
  - Reactor can be cooled without feedwater flow to the steam generator
  - All fuel can be cooled for a minimum of 72 hours without any BOP system
- Option of feeding steam from multiple reactors to a single turbine



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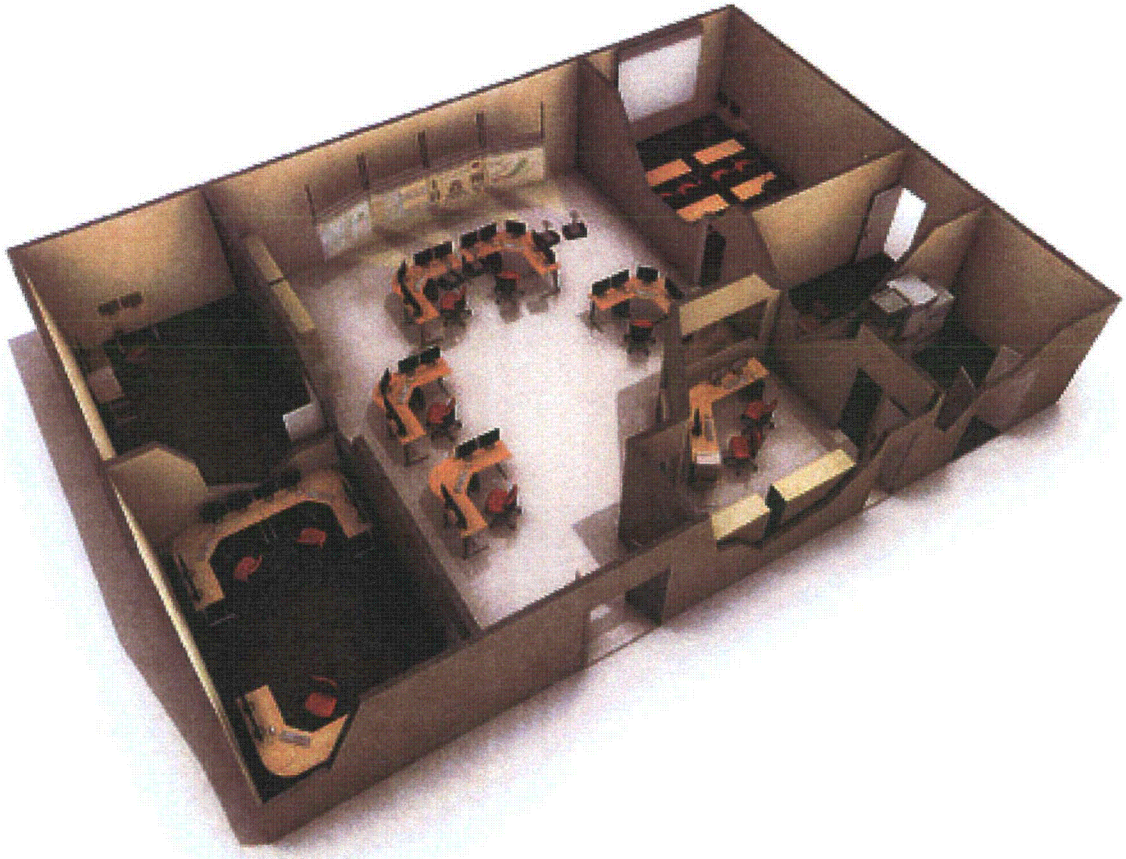
Instrumentation and Controls

- State of the art digital system
- Provides monitoring, control, and protection functions
- Separate safety and non-safety systems
- Implement lessons learned from current licensing activities



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Summary

- B&W *mPower* reactor based on demonstrated B&W technology
- B&W *mPower* design provides significant benefits
  - Integral reactor allows improved safety position
    - Core remains covered and cooled in postulated design basis accidents
    - Core cooling provided by passive safety systems and features
  - Conventional core design with low power density
  - No reliance on emergency diesel generators
  - Containment integrity ensured by passive cooling
  - No soluble boron used for reactivity control
  - Extended fuel cycle
  - 60-year fuel storage in containment
  - Below grade containment
- Incorporates conventional Balance of Plant design
- Uses digital I&C architecture

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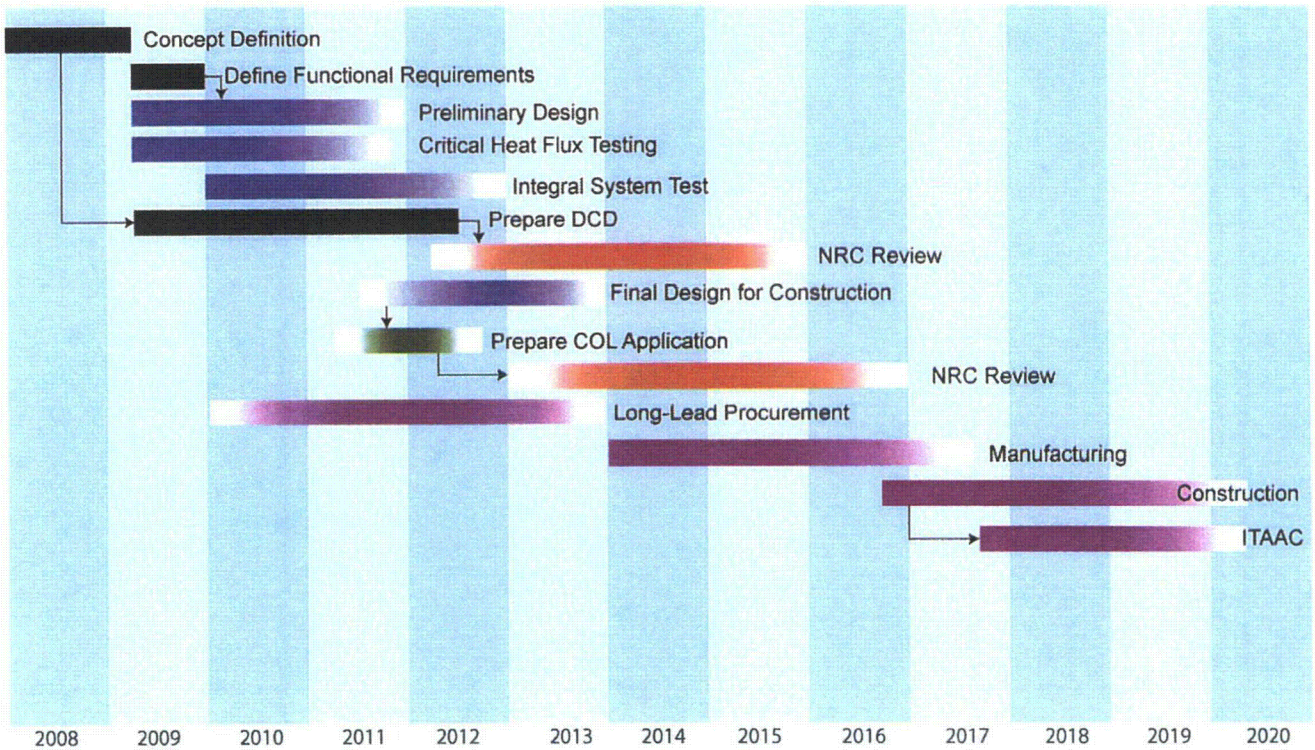
B&W mPower Lead Plant Schedule



- NRC review window 2012-2014
  - Initial ALWR reviews finishing
  - B&W/partner investments ongoing
- Initial ALWRs online 2017-2020
  - Considered ALWR by industry
  - Customers seek scalable options
- DCA submittal 1Q 2012
  - Nuclear Island design review-ready
  - Safety analyses substantially complete
- Lead COLA submittal 2013
  - Maintain NRC engagement
  - Lead plant operational 2018-2020

Critical external constraints ... NRC review window and initial New Build viability

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B&W *mPower* Pre-Application Work

Proposed Topical Report Submittals

Human Factors Program Plan	Dec 2009
QA Program description	Mar 2010
Core/fuel design criteria and analysis methodology	Mar 2010
Reactivity control	June 2010
Multi-module control room and operations staffing	June 2010
Safety analysis	Sep 2010
Design verification testing program plan	Sep 2010

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B&W mPower™
a progressive energy solution

B&W
nuclear power generation

Human Factors Engineering

October 27, 2009 NRC Meeting

Approach to B&W *mPower*™ Human Factors Engineering – Design Process

- Overview of the HFE approach for the *mPower*™ Reactor Design Process.
- Review contents of DCD Chapter 18 and the HFE Topical Report.
- Initiate dialogue with NRC Staff regarding HFE Plans.

Approach to B&W *mPower*™ Human Factors Engineering – Design Process

- HFE Program
  - Regulatory Guide 1.206 Compliant
  - Comprehensive Program Plan
  - Standard Process

Phases & Elements of HFE Program

Planning	Design	V&V	Implementation
1. HFE Program Management			
2. Operating Experience Reviews	7. Human-System Interface Design		11. Design Implementation
3. Functional Requirements Analysis & Function Allocation	8. Procedure Development	10. Human Factors Verification & Validation	12. Human Performance Monitoring
4. Task Analysis	9. Training Program Development		
5. Staffing & Qualification			
6. Human Reliability Analysis			

NUREG-0711 Twelve Elements

Element 1: Program Management

- General Program Goals and Scope
- Team Organization
- Process and Procedures
- Issues Tracking
- Technical Program

NUREG-0711 Formal Process

Element 2: Operating Experience Reviews

NRC Human Factors Information System (HFIS)

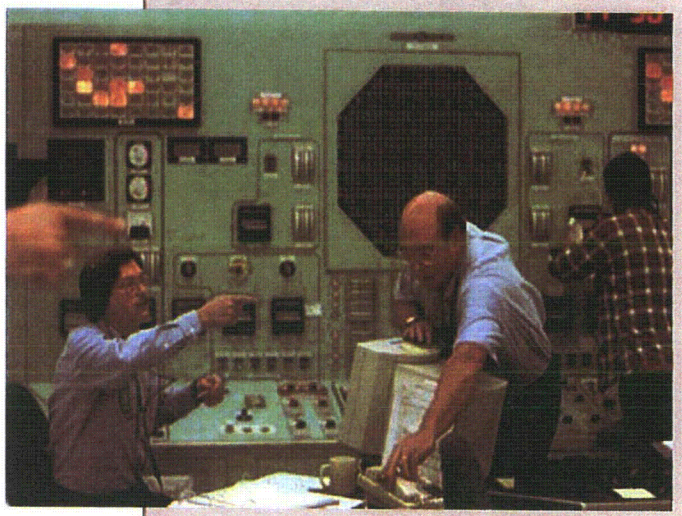
Table C1

HFIS LER Information
Root Cause Category for Types of Work Performed

From: 01/01/92 to Present
Number of LERs: 3786
Number of Human Performance Items: 8718

Root Cause Category

Work Type	Comm.	HSI	Mgmt.	Procedures Maint.	Training	Work Factor	TOTAL
Administrative	68	10	125	242	59	123	627
Calibration	45	26	45	95	31	59	301
Control Room Ops	443	138	513	489	282	449	2314
Design	132	16	314	161	76	120	819
Maintenance	250	74	202	276	169	286	1257
Modifications	142	20	158	138	49	81	588
Refueling	37	6	16	26	20	18	123
Testing	360	154	502	672	258	538	2484
Troubleshooting	46	13	29	34	32	51	205
TOTAL	1523	457	1904	2133	976	1725	8718

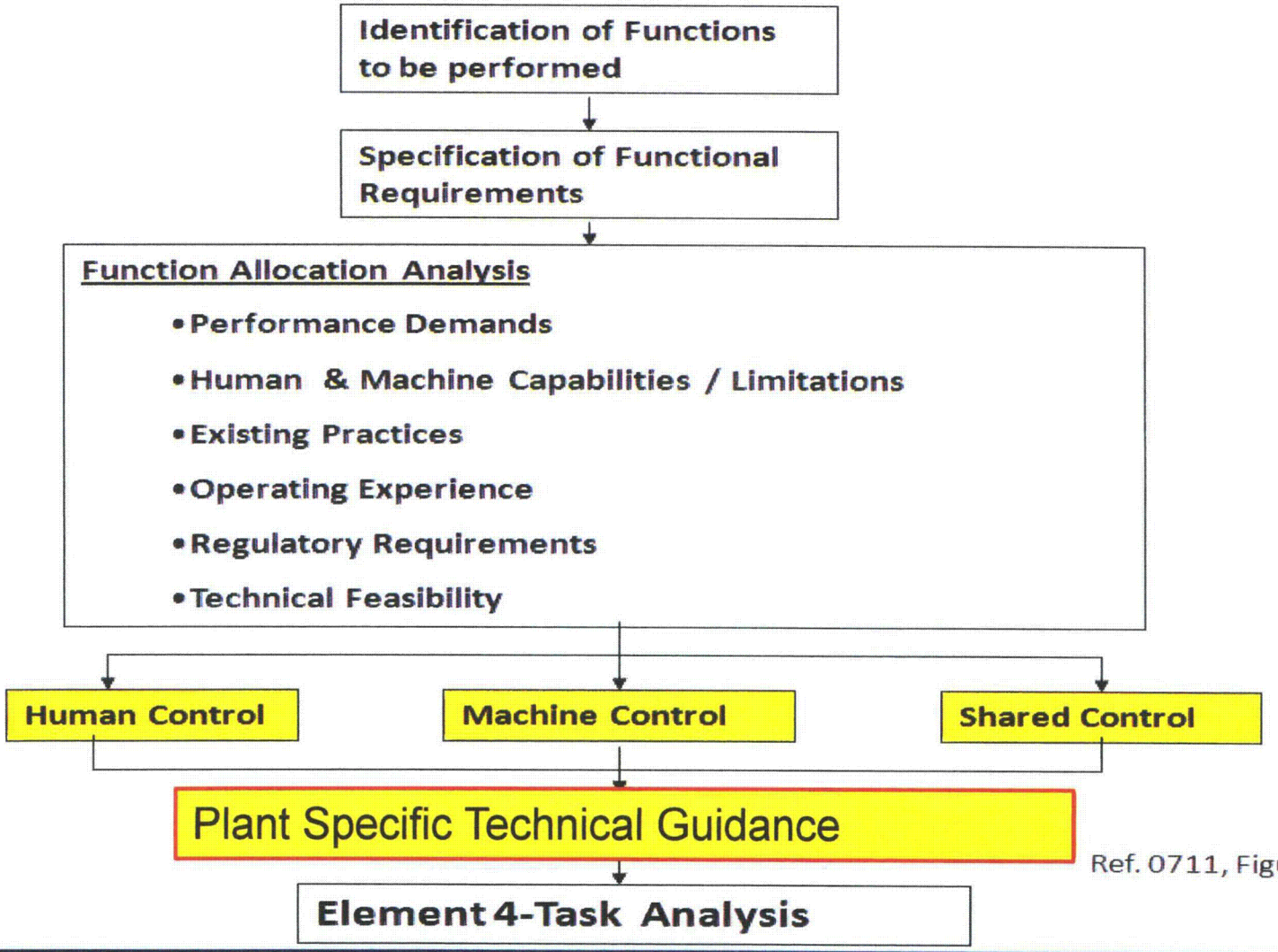


Predecessor Design Experience

Element 2: Operating Experience Reviews

- Examples of Modern Design in Areas of:
  1. Control Systems
  2. Display Systems
  3. Alarm Systems
  4. Computer-Based Procedures
  5. Workspace

Element 3: Functional Requirements Analysis & Function Allocation



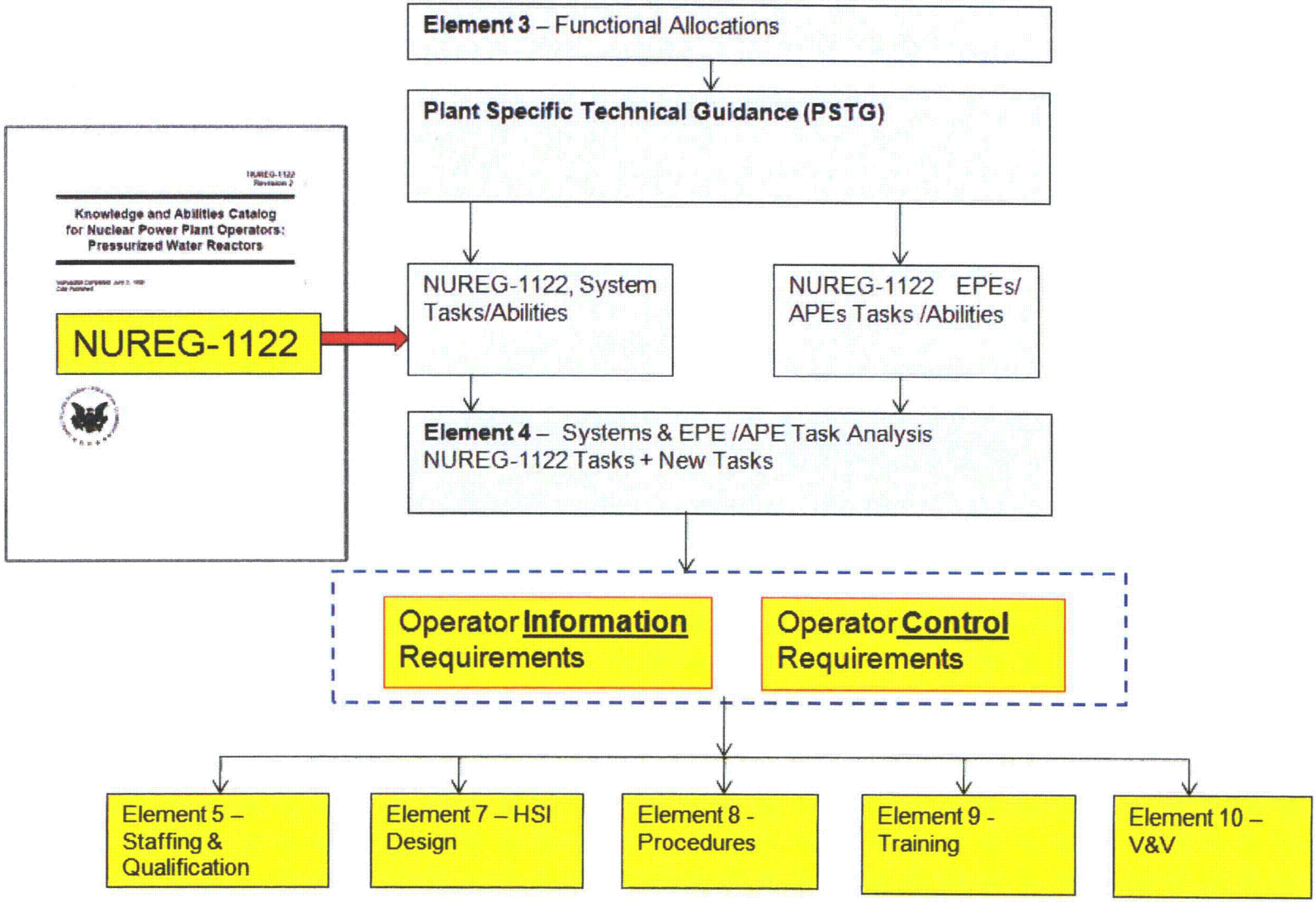
Ref. 0711, Figure 4.1

Element 3: Functional Requirements Analysis & Function Allocation

- Plant Specific Technical Guidance
  1. Physical connections
  2. Cause & effect relationships
  3. Power supplies
  4. Effect of system malfunctions
  5. Design features & interlocks
  6. Effect of component malfunctions

NUREG-1122
Link

Element 4: Task Analysis



Element 4: Task Analysis

NUREG – 1122 Ability Statements

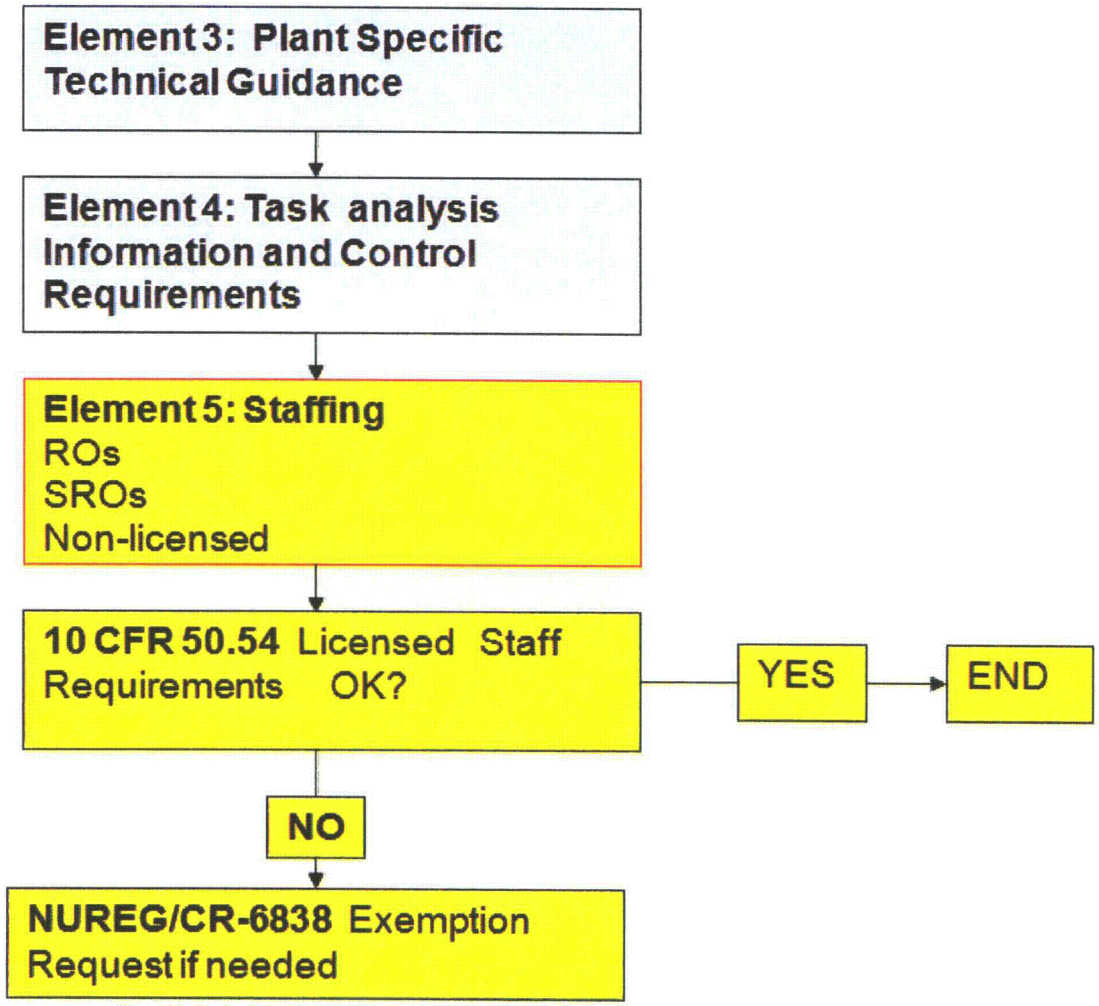
1. Knowledge physical connections / cause and effect relationships
2. Knowledge power supplies
3. Knowledge effects of system malfunctions
4. Knowledge of design features and interlocks
5. Knowledge operational implications
6. Knowledge of effects of component malfunction

operator information and control needs

1. **Ability to predict and monitor**
2. **Ability to predict the impact of malfunction**
3. **Ability to monitor automatic functions**
4. **Ability to manually operate**

Linked to 10 CFR 55

Element 5: Staffing & Qualifications



Element 6: Human Reliability Analysis

- Risk informed methodology
- NUREG-1792, Good Practices for Implementing Human Reliability Analysis (HRA)

Element 7: Interface Design

- Examples:
  1. Workspace design
  2. Workstation design
  3. Control Systems
  4. Display systems
  5. Alarm systems

Element 8: Procedures Development

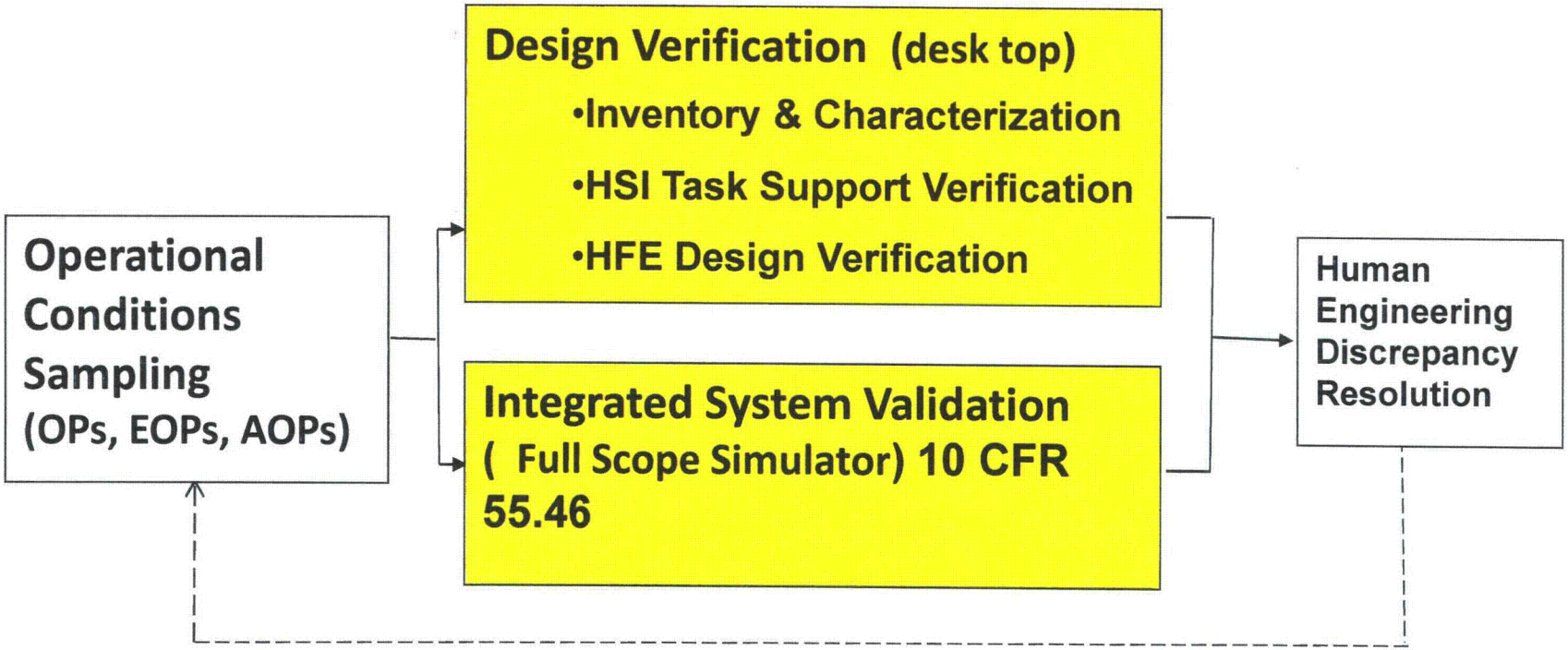
- NUREG-0800, Section 13.5.2.1
- DOE Standard 1029, Writer's Guide for Technical Procedures

Element 9: Training Development

- NUREG-1122 for Licensed Operators
- NUREG-0800 for Non-Licensed Staff

Element 10: Verification & Validation

NUREG-0711, Figure 11.1



Overview of verification and validation activities

Final Implementation Elements

Element 11: Design Implementation

Element 12: Human Performance Monitoring

Standard NUREG-0711 Process

Summary

- Approach to B&W *mPower*™ Human Factors Engineering Design Process:
  - Reg. Guide 1.206 Compliant
  - Comprehensive Program Plan
  - Standard Process

NRC Topical Report Submittal Procedure

- Topical Report Identifier
- Abstract
- Handling of Proprietary Information
- Topical Report Content
  - Planning & Management of HFE Activities
  - Plant Design Process