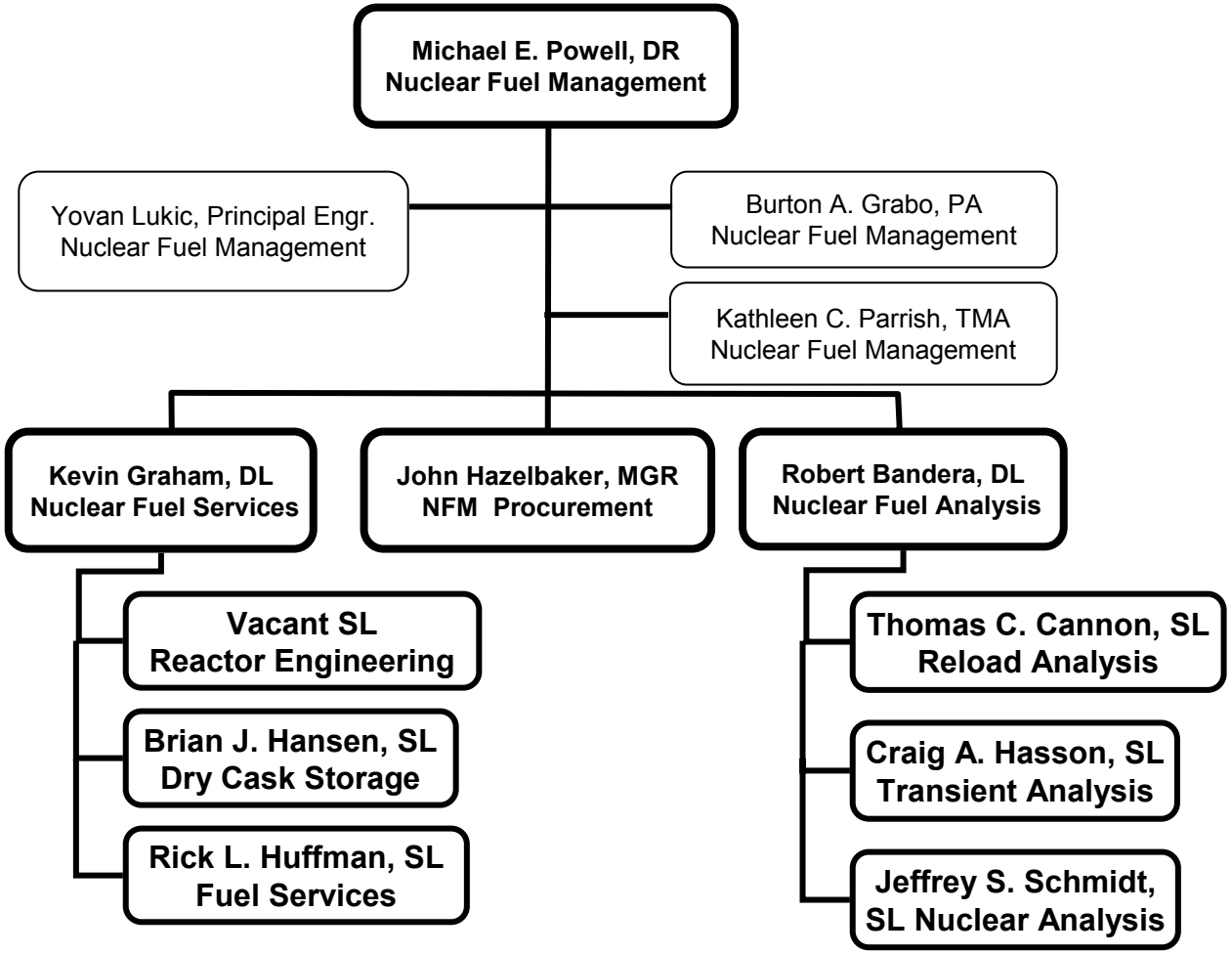
# Nuclear Fuel Update

## Palo Verde Nuclear Generating Station

**November 16, 2006**
**Meeting with US NRC**

# Nuclear Fuel Management



# Review of 2005-2006

- December 2004 Meeting with NRR
- SG Replacement & Power Uprate
- Dry Cask Storage Successes
- SIMULATE Implementation
- Augmented AORs
- New Top Grid Design
- New CEAs & LFA Projects

# Agenda Today

- CEA Replacement
- Dual LFA Program
- Fuel Performance
- Dry Cask Storage Update
- Planned License Submittals

# CEA Replacement

# Review of CEA History

- Felt Metal Wrapped Pellets in Tips
- CEA Clad Failures Observed - 2001
  - Cracks in High Fluence CEA Tips
  - Root Cause - IASCC, Inadequate Testing
- All Full Length CEAs Replaced
  - Replaced with Small Pellet Design
- Lifetime Software Abandoned

# Determination of New Lifetime

- ♦ Inspection versus Replacement
- ♦ Monitored YGN Inspections
- • 5 Cycle Lifetime:
  - – Vendor Adjusted Software
  - – Inconel IASCC Threshold

⇒ Need New CEAs for Fall 2008

# Design of Future CEAs

- Want:
  - Industry Standard AgInCd
  - Extended Tip Region
- CEDM Weight Restrictions
  - AgInCd Tip Region
  - Boron Carbide for Remainder
- Lifetime
  - ~20 EFPY Design Lifetime
  - ~12 EFPY Experience Base (Hot Cell)
  - ~18 EFPY Experience Base (PIE)

# Analysis & Licensing Impacts

- AgInCd Tip 75% Worth (vs. 90%) of B4C
- CEA Misoperation Events Bounded
- Scram Reactivity Curves Have Margin
- LOF & SS/SR Being Reanalyzed
- Tech Spec 4.2.2 Needs Revision

# Dual LFA Program

# Specific Fuel Design Goals

- Materials for Higher Burnup/Duty
  - Cladding Oxidation
  - Dimensional Stability
- Preserving/Increasing Operating Margins
  - Minimize CRUD
  - Increase Thermal Margin
- Improve Fuel Utilization
- Overall Robust Design for Flawless Fuel

# Lead Fuel Assembly Program

- Fuel Contract Timeline
- LFAs Needed to Demonstrate New Design
  - Observe Performance in Both PV Duty Cycles
  - 8 Assembly, 3 Fuel Cycle LFA Programs
- AREVA and Westinghouse Designs
  - M5 (AREVA) and Optimized Zirlo (WEC)
  - “Mixing Vane” Grids and IFMs in Spans 8 & 9
  - Gadolinia (AREVA) and IFBA or Gd (WEC) BAs

# Analysis & Licensing Strategy

- Explicitly Model LFAs in Core Physics Model
- Maintain Within > 5% of Limiting Assembly
- Rod Burnup Will Remain < 60,000 MWD/T
- Vendors Perform Mechanical, Thermal Hydraulic & LOCA Analyses
  - AREVA to Assure Non-Limiting
  - WEC to Assure Compatibility
- APS Performs Standard Reload Safety Analyses

# Analysis & Licensing Strategy
(continued)

- Safety Limits Preserved by Maintaining LFAs non-Limiting
- Transient Analyses Explicitly Validated
- COLSS & CPC Setpoints Explicitly Calculated
- 10CFR50.46 Exemption for M5 Required
  - Expect Exemption for Optimized Zirlo
- Evaluating Need for Tech Spec Changes

# 4.2.1 Fuel Assemblies

- Fuel assemblies shall be limited to those fuel designs that have been analyzed with applicable NRC staff approved codes and methods and shown by tests or analyses to comply with all fuel safety design bases
- A limited number of lead test assemblies that have not completed representative testing may be placed in non-limiting core regions
- Other cladding material may be used with an approved exemption.

# 2.0 SAFETY LIMITS (SLs)

- **2.1.1.1 In MODES 1 and 2, Departure from Nucleate Boiling Ratio (DNBR) shall be maintained at > 1.34.**

- **2.1.1.2 In MODES 1 and 2, the peak fuel centerline temperature shall be maintained < 5080°F (decreasing by 58°F per 10,000 MWD/MTU for burnup and adjusting for burnable poisons per CENPD-382-P-A).**

# Palo Verde
# Fuel Performance

# Fuel Clad Performance

## Clad Performance in Uprate Conditions

## High Burnup Fuel Performance

# Clad Performance in Uprate Conditions

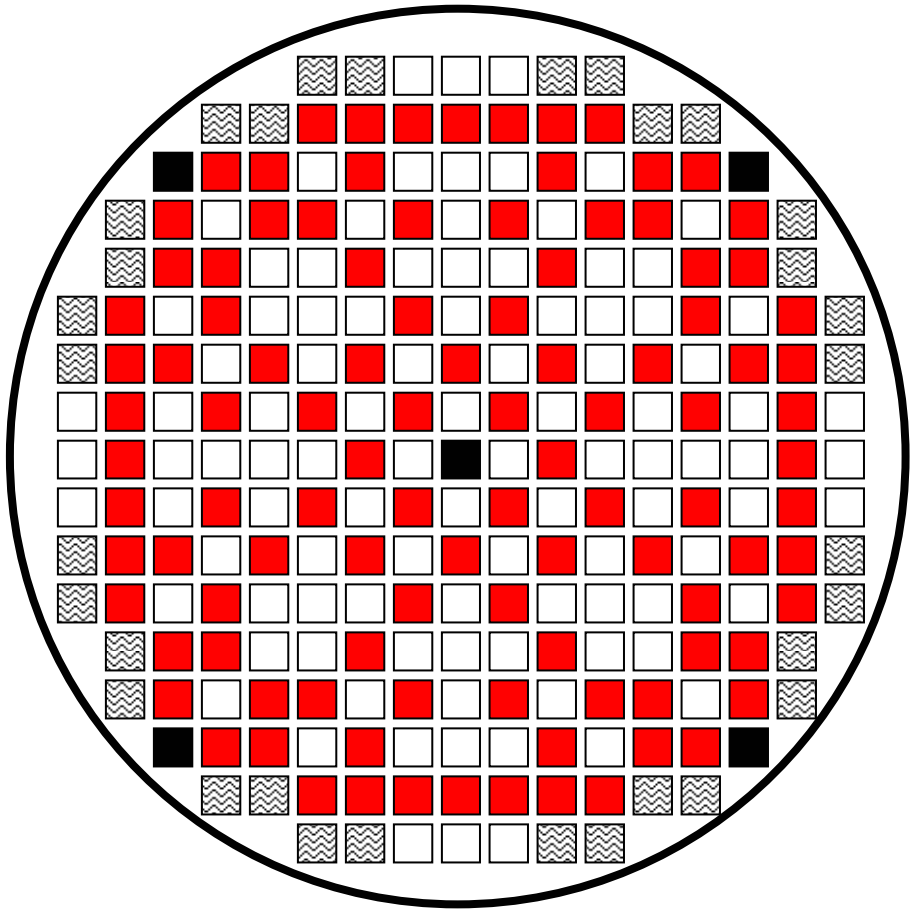
- 3% Power and ~4°F Inlet Temperature
- New Steam Generators
- Increased Clad Oxidation
- Increased Steaming Rates
  - Each 1°F or 1% Power is Worth 10% Steaming Rate
  - Higher Source Term from New Steam Generators
  - CRUD & AOA Risk

# Integrated Clad Performance Strategy

- Advanced Clad Alloy
- Primary Chemistry
- CRUD and Oxide Software
- Three Enrichment Lattice Designs
- Long Range Fuel Inspection Plan

# The Two Duty Cycles

## Typical (U2C13) Core Design



Fresh
1x burned
2x burned
Reinserts

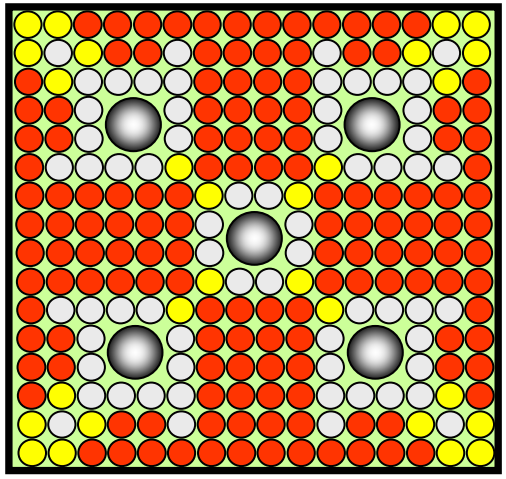
# ZIRLO™ Clad

- Westinghouse Low Tin Zirconium Based Alloy
- Protect High Duty 2 Cycle Assemblies
  - First Implementation in Unit 2 Cycle 11
- Licensing Limitations
  - Fuel Duty Index & Maximum Oxide Thickness
  - Vendor Oxide Software for Core Design Assessment
- 2R11, 2R12 & 2R13 Inspection Results
  - Performance as Expected

# 3 Enrichment Lattice Design

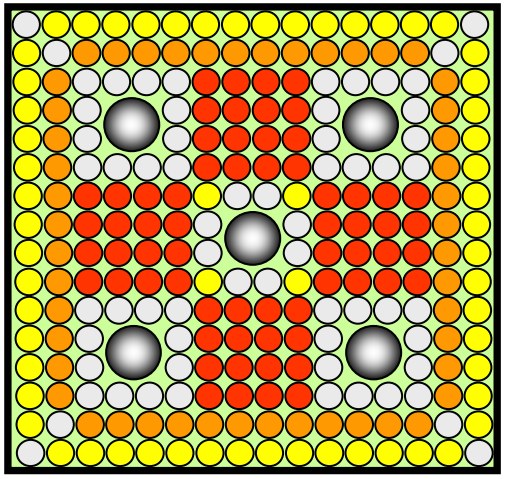
- **Protect High Duty First Burn Assemblies**
  - **First Implementation in Unit 2 Cycle 12**
- **Design Concept – Balance Power & Flow**
  - **In-House Designed Based on APS CRUD Model**
  - **Three Enrichments, Four Pin Types**
- **Inspection Results**
  - **2R12 – No CRUD**
  - **2R13 – Threshold CRUD**

# Sample Lattice Comparison



Previous - 64 Er

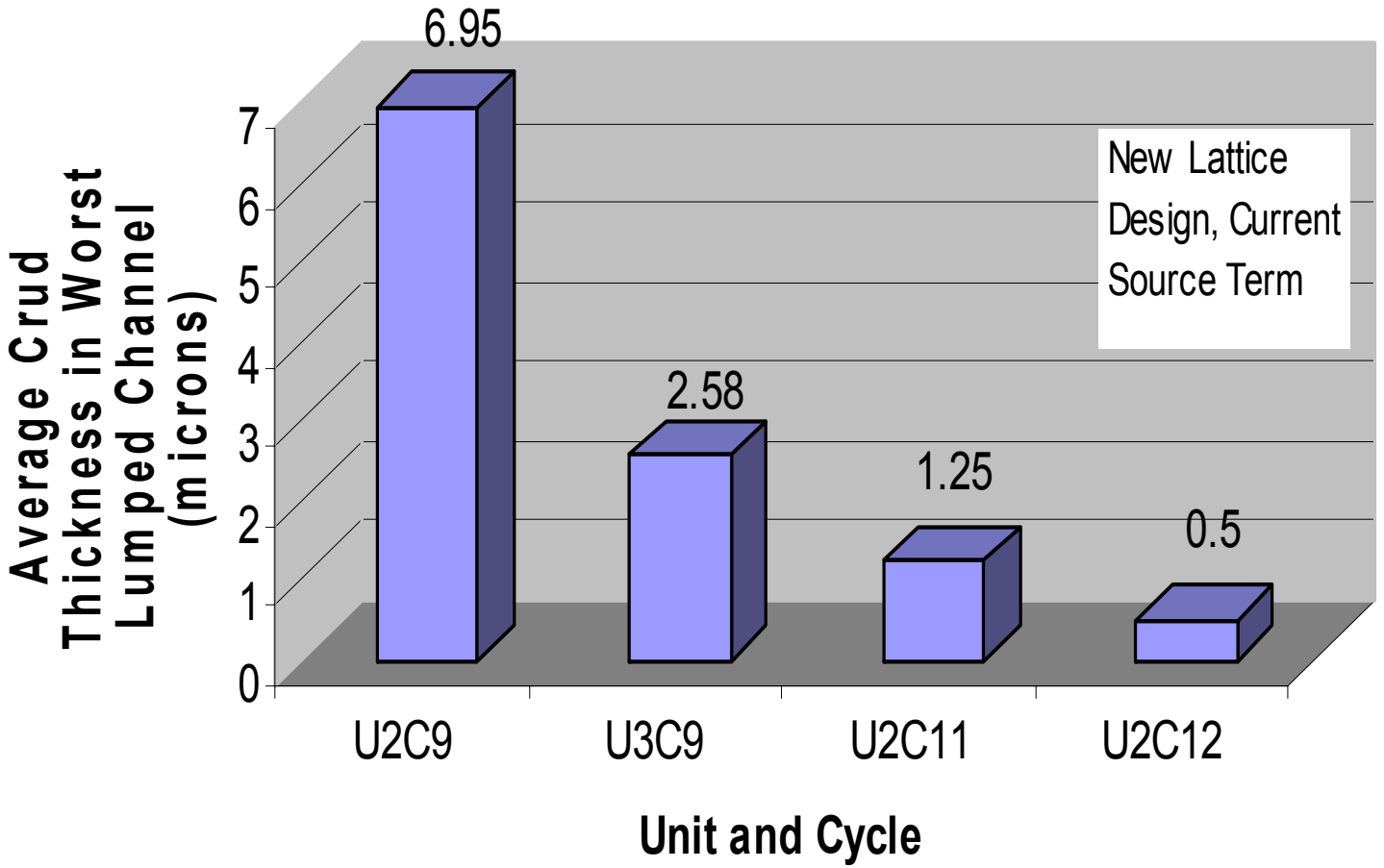
- 4.05 w/o
- 3.75 w/o
- 3.75 w/o Er



New - 64 Er

- 4.29 w/o
- 3.99 w/o
- 3.79 w/o
- 3.79 w/o Er

# Comparison of Average Crud Thickness - Predicted



# High Burnup Fuel Performance

## High Burnup Fuel Failure Trend

## Loose Top Grid Cells

## Top Grid Re-Design

# Flawless Fuel

- New Agreement with Westinghouse
  - Identify and Investigate All Failures
  - Incentive for Flawless Fuel
  - Reconstitute Failed Assemblies
- Sipping in Containment
- UT in Spent Fuel Pool

# High Burnup Fuel Failure Trend

- Mid 90's, Clean Cores Cycle After Cycle
- Ten Failed First Burn Pins in U2C9
- One Failed End Cap Weld (U1C9)
- Nine Indications Starting with U2C9
- Five of Nine Cycles with 1 or 2 Indications
- Three Identified Grid-Rod Fretting Failures
- No Current Operating Failures

# Loose Top Grid Cells

- PV1P Fabrication Campaign
- Root Causes
  - Bias in Grid Construction Tolerances
  - Force-Fit of 20 mil Oversize Guide Tube
  - Rod Pushing Table Mis-Alignment
  - Weaknesses in Inspection/QA Process

# Top Grid Re-Design

- Zirc-4 to Inconel 625
- Wavy strip to Straight Strip
- Cantilever Spring Cut-out
- Double Back-up Arch
- Accommodation of Expanded Guide Tube
- Grid to Guide Tube Attachment
- Change to “Top Nozzle” (UEF)

# Dry Fuel Storage Update

- ISFSI in Production 4 Years
- 47 Casks on the Pads
- Doses Consistently Under 50 mR
- Need NAC Amendment #5 12/07

# Planned License Submittals

# Planned License Submittals

- TS 3.1.6 Shutdown CEA Insertion Limits (2006)
- TS 5.6.5 Core Operating Limits Report (Summer 2007)
- 10CFR50.46 Exemption for M5 (Summer 2007)
- TS 2.1.1 Fuel Safety Limits (Summer 2007)
- TS 4.2.2 CEA Design (Fall 2007)
- Revised Inlet Flow Uncertainties (Fall 2007)
- Potential CEA Ejection with RAVE Methodology (2008)

# Shutdown CEA Insertion Limits

- Current T.S. Allows Insertion to 144.75” Withdrawn
- Safety Analysis Only Covers Insertion to 147.75”
  - Sufficient Additional Shutdown Margin Verified
  - Guide Tube Wear Program Controlled to 147.75”
- Shutdown Margin is Monitored per Core Data Book
- T.S. 3.1.6 rewritten to 147.75” withdrawn
- Submitted to NRC Summer 2006 (Requested 6/07)

# Core Operating Limits Report

- Inconsistent CEA Drop Reference
- Currently Processing Changes
  - Remove CESSAR References
  - Add 3990 MW Power Uprate References
  - Add Topical Report of 2nd Tier References
- Expected Submittal Date: Summer 2007

# M5 Clad Exemption

- Fall 2008 Insertion of AREVA LFAs
- M5 Already in Use
- M5 Not Listed in 10CFR50.46
- Expected Submittal Date: Summer 2007

# TS 2.1.1 Safety Limits

- Potential TS Submittal to Allow for LFAs
- TS 2.1.1.1 DNBR
  - Allow for Alternate CHF Correlation
- TS 2.1.1.2 Centerline Melt Temperature
  - Allow for Alternate Burnable Absorbers
- Potential Submittal Date: Summer 2007

# TS 4.2.2 CEA Design

- Tech Spec 4.2.2 states:

  "The control section for the full strength CEAs shall be boron carbide with Inconel Alloy 625 cladding"

- Needs to include AgInCd
- Expected Submittal Date: Fall 2007

# Revised Inlet Flow Uncertainties

- PV DNBR Limit Allows Statistical Combination of Inlet Flow Distribution Uncertainties
  - Within DNBR Limit or via Deterministic Penalties
- Re-Analysis of Experimental Data
  - Reduced Uncertainties
  - Reduced DNBR Penalties
- Potential Submittal Date: Fall 2007

# CEA Ejection with RAVE

- Current CEA Ejection AOR Precludes Fresh Fuel Under Lead Bank
- Considering RAVE Analysis
  - Core Design Flexibility
  - Improves Worth for Axial Control
  - Margin for New Criteria
- Potential Submittal Date: 2008