From Rehost to I/O System Replacement: A Major Simulator Upgrade for the Krsko NPP
L3 MAPPS Welcome Reception at the Waterfront

• Tonight at 7 p.m.
• All welcome!
• The Waterfront Bar & Grill
  – San Diego’s oldest tavern
  – Established in 1933
• 2044 Kettner Boulevard, San Diego, CA 92101
• 13 minutes walk from hotel
Topics

- Introduction
- Simulator Background and Project Objectives
- Scope of Work
- Project Schedule
- Conclusions
Introduction
Krško Nuclear Power Plant

- Operator: Nuklearna elektrarna Krsko (NEK)
- Vrbina, Municipality of Krsko, Slovenia
- Single-Unit
- Westinghouse 2-loop PWR
- 1,994 MWth
- 696 MWe
- Connection to grid on 2 October 1982
- Commercial operation since 15 January 1983
Simulator Background and Project Objectives
Simulator Background

- Originally built by L3 MAPPS (then CAE) and Ready for Training in 2000
- Silicon Graphics Origin 2000 Simulator Host Computers (UNIX)
  - Simex Plus (Simulator Executive)
  - ROSE® 2.4 (Modeling Environment)
  - IOS (Instructor Station)
- Datapath SC I/O system
- MAAP4 Severe Accident Simulation
- Safety Upgrade Program (SUP)
  - Simulator Upgrade awarded to L3 MAPPS on 2 March 2016
Project Objectives - Global

- Implement Safety Upgrade Program consistent with the nuclear industry response to the Fukushima accident
  - Upgrade of Severe Accident Simulation from MAAP4 to MAAP5
  - Introduction of simulation of new Emergency Control Room
- Improve simulator maintainability by utilizing industry-standard state-of-the-art components
  - Operating platform
  - Software applications
  - Off-the-shelf PC-based computer network
- Introduction of Classroom Simulators
- Ability to continue maintenance and modification of the simulator without vendor assistance
- Turnkey solution
Project Objectives - Detailed

- Replacement of computer system to Windows Operating System
  - Introduction of simulation virtualization
- Replacement of simulation environment with Orchid® product suite
  - Including porting existing external systems communications drivers
- Upgrade various plant models related to Safety Upgrade Project
- Upgrade Severe Accident Simulation model from MAAP4 to MAAP5
- Retention of Simulator’s Main Control Room hardware panels
  - Replacement of the existing Datapath SC I/O system
- I/O system expansion for replacement of Remote Shutdown Panels (RSP) with new Emergency Control Room
- Introduction of Classroom Simulators with Orchid® Touch Interface hardware and software
Simulator System Block Diagram
Rehost to Orchid® Software Environment

Fully graphical, dynamic models

- T/H (ANTHEM™)
- Containment
- BOP
- I&C
- Electrics

SIMULATOR

Simulation Computer

PPC or DCS

Instructor Station

MCR Panels

*Not used for this project
Stimulated Systems

- Port existing communication drivers to the Windows platform
  - Stimulated Plant Information System (SPIS)
  - Turbine Control
    - Stimulated Programmable Digital Electric Hydraulic (PDEH)
  - Fire Protection System
    - Already using Orchid® Control System [via previous upgrade]
  - Source Counter
  - Radiation monitors
  - Main Control Room light controller
    - CSLDIS monitor
Simulation Servers Virtualization

- Two servers connected to a common disk array
- Each server capable of simultaneously running a virtualized Full-scope simulation and a backup/development machine
- Rapid switchover with no loss of data if a server fails (seamless to the user)
- Countermeasure for hardware and operating system obsolescence
  - Virtual machines can be installed on newer platforms with minimal effort and cost
Plant Models Upgrade

- **Modification 1007-XI-L (Emergency Control Room)**
  - Update the model software to take into account the removal of the RSP and addition of new ECR
  - Modifications to the soft (virtual) panels and the simulation models to account for the ECR and transfer panels

- **Modification 1058-NA-L (ECR/TSC HVAC and habitability systems)**
  - Simulation of the air conditioning units

- **Modification 1094-HD-L (HD control system software and hardware upgrade)**
  - Simulation of the new HD SCADA HMI using Orchid® Control System
  - Existing models for the HD logic retained and interfaced to the simulated HMI

- **Modification 1025-RC-L (PRZR PORV Bypass)**
  - Update the existing pressurizer model for the additional PORV and add associated logic
Plant Models Upgrade

• Modification 1028-SF-L (SFP Alternate Cooling)
  – Replace the spent fuel model with an upgraded version that takes into account the plant modification and associated logic
  – Alternate cooling systems interfacing to the MAAP5 spent fuel pool model during severe accident simulation
• Modification 1029-RH-L (Alternate RCS and Containment Cooling)
  – Simulation of the alternate RCS and containment cooling systems and associated logic
• Modification 1137-EE-L (Enhancing Bunkerized Building 1 [BB1] Electrical Distribution)
  – Update the electrical distribution model to account for BB1 modification
• Modification 1140-RC-L (Replacement of the ICCMS control cabinets)
  – Update the existing ICCMS model to account for the BB1 modification
  – Simulate 15 displays of the ICCMS HMI using Orchid® Control System
Orchid® Modeling Environment

- Complete object libraries
- Libraries can be modified and augmented by partners and customers
- Online documentation for every component
- Modeling made easy!
  - Drag components from libraries
  - Connect all components by pointing & clicking in system being modeled AND to/from all external systems
  - Link to data sources by pointing & clicking to associated data in SharePoint
  - Use online calibrators to configure and fine tune systems
- Full visual, RUNTIME feedback (systems, components, real-time values)
- System Documentation generated on-the-fly
- All variables are accessible
- On-the-fly calibration
- Point & click to browse to surrounding systems
- User defined real-time plotting and variable monitoring
- Runtime graphics available in Instructor Station for full control
Migration from MAAP4 to MAAP5 Severe Accident Simulation

- Krško FSS was L3 MAPPS’ first simulator to incorporate severe accident simulation based on MAAP4 (RFT in 2000)
- MAAP5 enhancements and new features
  - A spent fuel pool model capable of modeling SFP severe accidents
  - Natural circulation flows in the core, the hot leg and steam generators, before and after the core is uncovered
  - Improved computation to handle a greater range of transients
  - Increased capability for Steam Generator Tube Ruptures (SGTRs), Main Steam Line Breaks (MSLBs), Loss-Of-Coolant Accidents (LOCAs) analyses which require better steam generator models
  - The PWR reactor coolant system (RCS) models have continued to advance as the requirements for MAAP have evolved

MAAP5 is an Electric Power Research Institute (EPRI) software program that performs severe accident analysis for nuclear power plants including assessments of core damage and radiological transport. A valid MAAP5 license to MAAP5 from EPRI for customer’s use of MAAP5 is required prior to a customer being able to use deploy MAAP5 with Licensee’s simulator products.

EPRI (www.epri.com) conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public. As an independent, nonprofit organization, EPRI brings together its scientists and engineers as well as experts from academia and industry to help address challenges in electricity, including reliability, efficiency, health, safety and the environment. EPRI does not endorse any third party products or services. Interested vendors may contact EPRI for a license to MAAP5.
Migration from MAAP4 to MAAP5 Severe Accident Simulation

- Fully integrated to enable complete simulator control and functionality
  - Complete Instructor Station control
    - IC store/restore
    - Malfunction implementation
    - etc.
  - Switching between L-3 MAPPS’ ANTHEM™ thermal-hydraulics model and MAAP5 models handled via Orchid® Modeling Environment interface schematics
Enhanced 3-D Visualization to View NSSS Equipment and Properties
Quick Demonstration

4-loop PWR example. Krško is a 2-loop PWR.
Display System Emulation using Orchid® Control System

- Orchid® Control System used for the emulation of PPC/DCS systems
- Orchid® Control System based on real-time data acquisition and control system
- Built-in
  - Operator station functions
  - Graphic editor
  - Interfaces to L3 MAPPS’ simulations
  - Database maintenance tools
  - Historical Data
  - Alarm and Event Logger
- Inherent support for simulator commands
I/O System Replacement

- **I/O System**
  - MCR I/O Count: 16,368 signals
  - New ECR I/O Count: 2,224 signals
- **Replace the legacy Datapath SC I/O system**
  - with new Beckhoff Compact I/O system
- **Hot-swappable Instrument Power Supplies**
Orchid® Input Output Solution

Simulation Server

- Communication of simulator data to all I/O nodes
- Conversion from engineering units to electrical units

• Provides necessary features to
  – Configure
  – Maintain
  – Troubleshoot

...the entire I/O system
I/O System Replacement

Junction Modules

Digital Rod Position Indicators (DRPI)

Use of flat ribbon cable connectors to interface directly with the Beckhoff I/O modules

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Orchid® Multimedia Manager

- Records all audio and video feeds individually
- Fully synchronized with the simulation

- Uses commercial-off-the-shelf audio/video cameras and mics
- Provides all required features for effective monitoring by instructors and for operator debriefing
Orchid® Sound System

• Multi-channel system with full control of individual sound volume and frequency
  – ECR and MCR can play different sounds simultaneously
• Subwoofers for earthquake simulation
Orchid® Touch Interface – Classroom Simulator

• NEK to receive two (2) Orchid® Touch Interface bays for MCR classroom training and custom Orchid® Touch Interface hardware for local panels training

• Full scale control room training environment using touchscreen technology

• Life-like training environment to augment the current full scope simulator environment

• Orchid® Touch Interface bays designed for mobility

• All cables and computer hardware contained in bays

• Large full-HD LED touch monitors

• Close to life-size virtual panels

• One bay useful for targeted training

• Numerous bays can reproduce entire control room

Local Panels Classroom Simulator

Main Control Room Classroom Simulator
Project Schedule
Project Schedule

AOC: Award Of Contract
ECR: Emergency Control Room
FAT: Factory Acceptance Testing
MCR: Main Control Room
RFT: Ready For Training
SAT: Site Acceptance Testing

Rehost Factory Acceptance Testing Completed (15 December 2016)

Current Status
Conclusions
Conclusions

• NEK and L3 MAPPs have a long history of working well together

• With the latest Orchid® simulation platform, NEK personnel will be able to continue easy day-to-day maintenance and further upgrading of the simulator for its lifecycle

• The project maximizes use of commercial-off-the-shelf components and third-party software for computers, I/O and peripherals

• The Krško simulator will feature the latest MAAP5-based severe accident simulation

• The simulator will benefit from state-of-the-art 3-D visualization

• The MCR and local panels classroom simulators will be used to augment NEK’s training capabilities
Thank you