Embalse Simulator for Training and Plant Life Extension

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Outline

• About L3 MAPPS
• Recent PHWR Simulator and Plant Life Extension Program
  – About Embalse Nuclear Power Station
  – Development of Full Scope Operator Training Simulator and Simulator Upgrade
• Conclusions
L3 Technologies
HQ: New York City
31,000 employees
US$9.6 billion (2017)
3 Business Segments

14 October 2018 Announcement:
L3 Technologies (NYSE: LLL) and Harris Corporation (NYSE: HRS) to merge. Merger expected to close in mid-2019.

L3 MAPPS
HQ: Montreal
3 Markets: Naval, Power Gen., Space
Control Systems (I&C) & Simulation

Global NPP Simulation Footprint
L3 MAPPS
Addressing your mission-critical control and simulation needs

Headquartered in Montreal, Canada

Marine Systems and Simulation
Over 250 ships, 22 navies

Power Systems and Simulation
Over 50 power generators, multiple engineering organizations

Space Systems and Simulation
CSA, ESA
Solutions Overview

L3 MAPPS Power Systems and Simulation

- Learning Modules
- System Knowledge Modules
- Learning Simulators
- Classroom Simulators
- Engineering Simulators

- Early Learning Technologies
- Full Scope Operator Training Simulators
- Severe Accident Simulation
- Simulator Upgrades & Modifications
- Part-task Trainers
- CANDU Plant Computers
A Proud History of Nuclear Power Plant Simulation Success

1973: Entered PHWR Simulation Business - Pickering A (Canada)

Today: Global Leader in Nuclear Power Plant simulation
2018 Event: Meet the Pioneers

- 2018: 45th anniversary
- Held town hall meeting with three founders of L3 MAPPS NPP simulation business
  - Montreal, 25 April 2018
- First-ever PHWR NPP simulator built 1973-1976
  - Pickering A (Canada)
- Pioneers
  - Q.B. (Jordan) Chou: President & CEO, Canadian Power Utility Services
  - Les White: Retired
  - George Bereznai: Professor & Dean, University of Ontario Institute of Technology
About Embalse

- 1 of 3 operating commercial nuclear plants in Argentina
- Operator: Nucleoeléctrica Argentina Sociedad Anónima (NA-SA)
- Located near city of Embalse, Córdoba Province
- Plant Type: PHWR (CANDU* 6)
- Commercial Operation: January 1984
- Gross Output: 648 MWe
  - Also produces cobalt-60 radioisotope for cancer therapy and industrial applications
- Life Extension Program by NA-SA
  - Extends life of plant for another 30 years
  - Reactor shut down in January 2016 for main work
  - Returned to service 4 January 2019
  - Increased Generation Capacity: 6%

*CANDU is a registered trademark of Atomic Energy of Canada Limited, used under license by Candu Energy Inc., a member of the SNC-Lavalin Group.

source: NA-SA
Development of Full Scope Operator Training Simulator and Simulator Upgrade
Full Scope Simulator Overview (Simplified)

Plant systems reproduced with software...

Schematic source: www.nuclearFAQ.ca
Control Room Photo source: NA-SA
Embalse Simulator Construction Timeline

1. Initial Full Scope Simulator Build
   - Contract Award: July 2010
   - Ready For Training: March 2013

2. Simulator Upgrade
   - Start: July 2015
   - Finish: February 2018
Simulator Architecture

• Major Elements
  – Simulator Control Room
    ▪ Full replica of plant control room
    ▪ Compact I/O System
  – Simulation Servers
    ▪ All plant simulation real-time computing
  – Digital Control Computers (DCCs)
    ▪ DCCs monitor and control all major reactor & power plant functions
    ▪ Emulated/virtual machine
  – Instructor Stations
    ▪ Controlling simulator training and monitoring student performance
Simulator Control Room

Simulator Replica Main Control Room

Rear View of Simulator MCR
Simulator Control Room (Rear)

Orchid®

- Ensures real-time communication between panel instrumentation and simulation servers via I/O controllers
- Provides online diagnostics
  - Node, Module, Channel
- Sends hardware and communication failure indications to Orchid® Instructor Station
- Graphical User Interface
Simulation Servers

- Commercial off-the-shelf computers (Dell)
- Windows operating system
- Simulation platform: Orchid®
- All simulator services and configuration management provided from Main Server (DCC emulation on separate server)
  - Simulator management (Orchid® Simulator Executive)
  - Plant models (Orchid® Core Builder + Orchid® Modeling Environment)
    - Approx. 90 plant systems simulated
  - Communications with MCR instrumentation (Orchid® Input Output)
  - Instructor Station (Orchid® Instructor Station)
- Backup Server available if needed and for concurrent development activities
Simulation Servers

- All plant systems modeled
  - Containment
  - Reactor
  - Nuclear Steam Supply System
  - Balance of Plant systems
  - Electrical systems
  - I&C Systems
Plant Modeling with Orchid®

Plant Documents Repository

Plant Documents *synchronized* with Simulation Models

Simulation Models *synchronized* with Plant Documents

Plant System Models (Orchid®)

Fully Integrated, Interactive Visual Simulation of Whole Plant

Used for Verification & Validation + Operator Training
Digital Control Computers

• Complete emulation of dual DCC (DCC X and DCC Y)
  – Display System: Emulated
  – DCC Executive & Control Programs: Virtual Machine
• Supports simulator functions and ability to display and override individual I/O points
• Provides full, multi-channel Display System capability
• Provides graphical view of the DCC X & DCC Y Program Activity Displays
• Provides additional tools for software maintenance
• Provides full DCC trending, printing and screen copy capability

Typical dual DCC arrangement (simplified). The DCC Emulation accurately reproduces all functionality of the plant DCC.
Instructor Stations

- Instructors control and monitor all aspects of simulator and trainee performance with Orchid® Instructor Station
- Fully graphical user interface
- Automatic scenario execution and data collection
- Automatic and manual evaluation and scoring of students
- Focused on automation of tasks and automation of data collection to simplify user experience
- Operable virtual panels allowing instructors to “override” panel devices
Simulator Validation & Testing

- All simulator model testing performed using plant procedures
- Simulator response validated against
  - Plant data (where available)
  - Safety Analysis Reports (for expected plant response to transients)
  - Similar PHWR plant response or data when no reference unit data is available
- Extensive testing program (Module Tests, Subsystem Tests, System & Intersystem Tests, Pre-FAT, FAT and SAT)
- Early participation of customer personnel (plant operators, engineers and instructor) is great asset to reduce number of deficiencies and testing phase durations
- Virtual panels are key testing tool while full replica of control room panels is being manufactured

Part of the testing team before the simulator was shipped to Argentina. L3 MAPPS used two separate test facilities for this project.
• While initial Full Scope Operator Training Simulator being built (2010-2013), plant Life Extension Project still ongoing
• Resulted in plant design changes that needed to be implemented on simulator
  – Simulator Upgrade (2015-2018)
  – Plant System Modifications
  – Numerous MCR Panel Changes
  – DCC Control Programs Upgrade
  – New simulator Audiovisual System for crew performance monitoring and debriefing
Simulator Upgrade Project

- Simulator Upgrade to plant systems in parallel with ongoing changes at the reference plant
- Implementation of Plant Life Extension changes on the simulator resulted in

**Positives**
- Identifying issues/conflicts in the design prior to completing work at plant
  - Approx. 16% of deficiencies during testing related to Plant Life Extension design changes
- Implementing and testing new designs on the simulator first
- Development and testing of new operating procedures by NA-SA
- Advanced training on the new system designs and new operating conditions

**Negatives**
- Introduced delays in Simulator Upgrade project
- More work for NA-SA to coordinate with other suppliers
New Audiovisual System

- Initial Full Scope Simulator build did not include an audiovisual system for instructors to monitor, record and debrief student performance
- Became clear that it was needed to facilitate the work of the instructors

- Added 6 HD PTZ cameras and 6 microphones in simulator control room
- Added 2 large screen displays in instructor booth
- Audiovisual equipment controlled by Orchid® Multimedia Manager
- Audio and video recordings time synchronized with instructor station
  - Allows time-synchronized playback of audio channels, video channels and other simulator data for effective student debriefing
Conclusions

• 2013 delivery of Full Scope Operator Training Simulator enabled NA-SA to provide quality, plant-specific training to Embalse operators

• 2018 Simulator Upgrade proved to be useful for identifying Plant Life Extension design issues and preparing operators in advance of plant returning to service

• Excellent relationship between L3 MAPPS and NA-SA
  – During projects, NA-SA was responsive and great help in project progress

• Operator Training Simulator can be used as V&V simulator for Life Extensions or NNB
  – If high-fidelity
  – But depends on training schedule
  – Another strategy is to use Engineering Simulator(s) for V&V for Life Extensions or NNB
    ▪ If planned properly

• L3 MAPPS investments in user-friendly Orchid® simulation environment continue to pay dividends

• Embalse has most advanced CANDU plant simulator in service worldwide
“NA-SA and L3 MAPPS put the Embalse full scope simulator into service in 2013 and we have experienced very positive training results since then. The simulator plays a key role in the ongoing training of our operators and will continue to be important as we extend the life of the plant for another 30 years.”
Thank You

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