

AI and Operational Decision Making for Autonomous Nuclear Facilities

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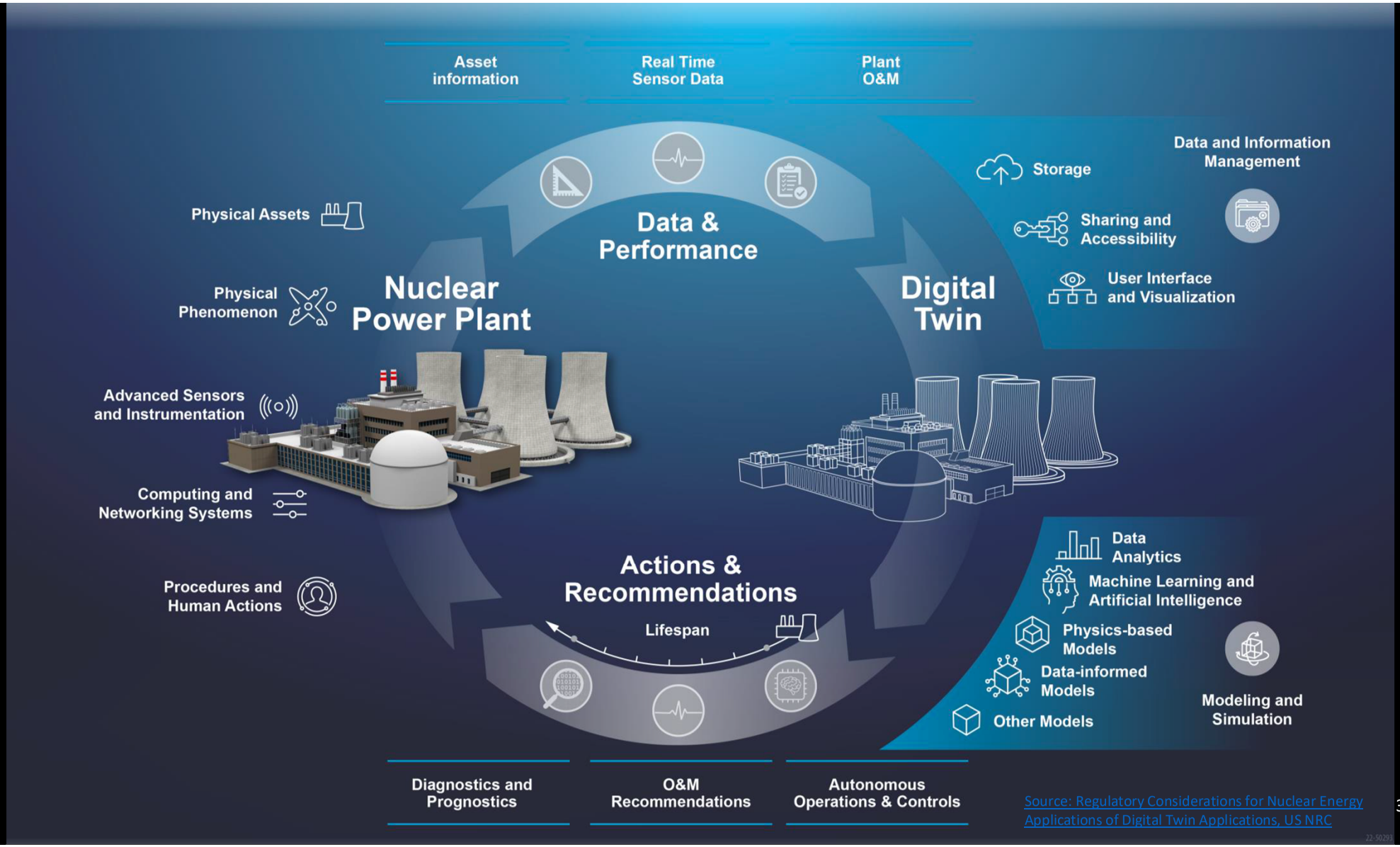






Develop and deploy **Small Modular Reactor (SMR)** technology as an alternative to fossil fuel generation in **off-grid** applications including **remote communities** and **mines.**

Provide a new form of **inherently safe, clean, reliable**, and **commercially viable energy** to Canada and other countries, owning and operating the next generation of nuclear technology.



Source: Regulatory Considerations for Nuclear Energy Applications of Digital Twin Applications, US NRC

NPP Automation

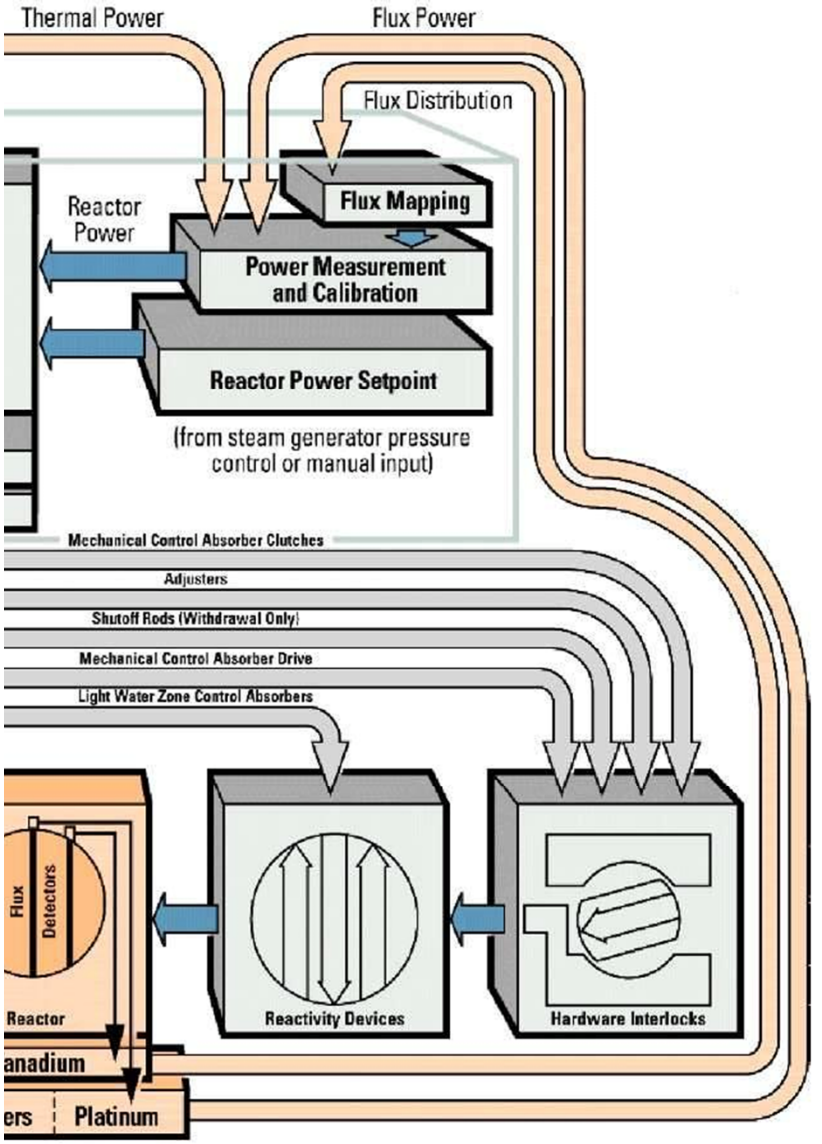
Levels of Automation for NPP Applications

	Level	Automation Tasks	Human Tasks	CANDU Example
1	Manual Operation	No automation	Operators manually perform all tasks	Pump start / duty swap
2	Shared Operation	Automatic performance of some tasks	Operators perform some tasks manually	Generator synchronization
3	Operation by Consent	Automatic performance when directed by operators to do so, under close monitoring and supervision	Operators monitor closely, approve actions, and may intervene to provide supervisory commands that automation follows	Heat Transport warmup Turbine runup ETS operation (EDG start, runup, synchronization & bus loading)
4	Operation by Exception	Essentially autonomous operation unless specific situations or circumstances are encountered	Operators must approve of critical decisions and may intervene	On-power fueling
5	Autonomous Operation	Fully autonomous operation. System cannot normally be disabled but may be started manually	Operators monitor performance and perform backup if necessary, feasible, and permitted	Reactor Control (RRS/RCS/ZTP)

Source: NUREG-0700, rev 3, Human-System Interface Design Review Guidelines, Section 9

Current Automation & Operational Decision Making

- CANDU Reactor Control
  - Complex multiple algorithms
  - 100s of I/C signal inputs & outputs
  - Reactivity device control
  - 200ms program execution
- Training of algorithms, control logic, inputs, failure modes, response
- ODM procedurally enabled:
  - Alarm & critical parameter monitoring
  - Safe state (margin for response)
  - Diagnosis / understanding
  - Actions to mitigate / safe state
- Safe state prioritization



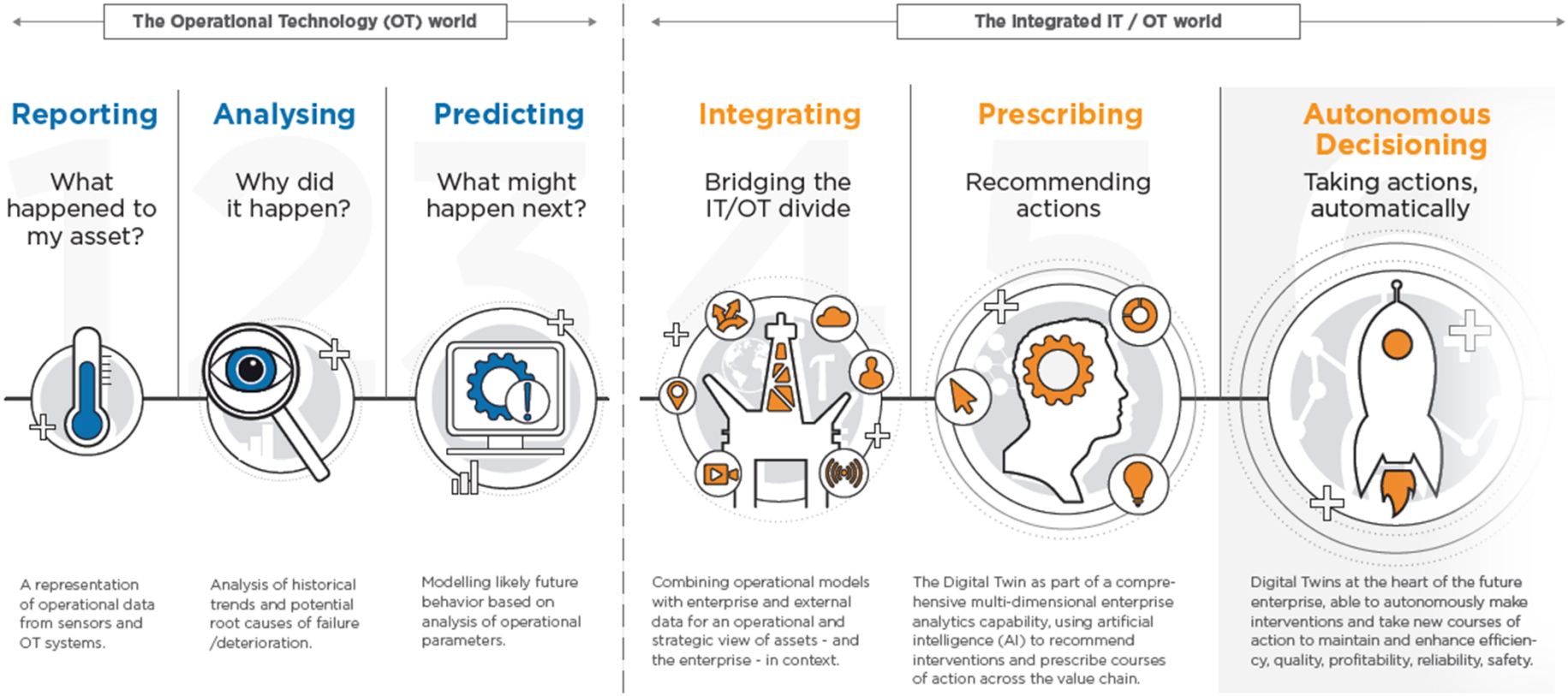
Future Automation & Operational Decision Making

- AI Risk Management Framework
  - Safe, secure & resilient, understandable
- Autonomous system design principles
  - **Explanation**: evidence or reason(s) for outputs and/or processes.
  - **Meaningful**: explanations are understandable.
  - **Accuracy**: explanations correctly reflect reason for generating output and/or accurately reflects the system's process.
  - **Limits**: only operates under conditions for which it was designed and with sufficient output confidence.
- HSI support for operator verification
  - Basis for automated actions and recommendations



Source: NIST AI Risk Management Framework (AI RMF 1.0)
Source: NIST Four Principles of Explainable Artificial Intelligence (NIST.IR.8312)

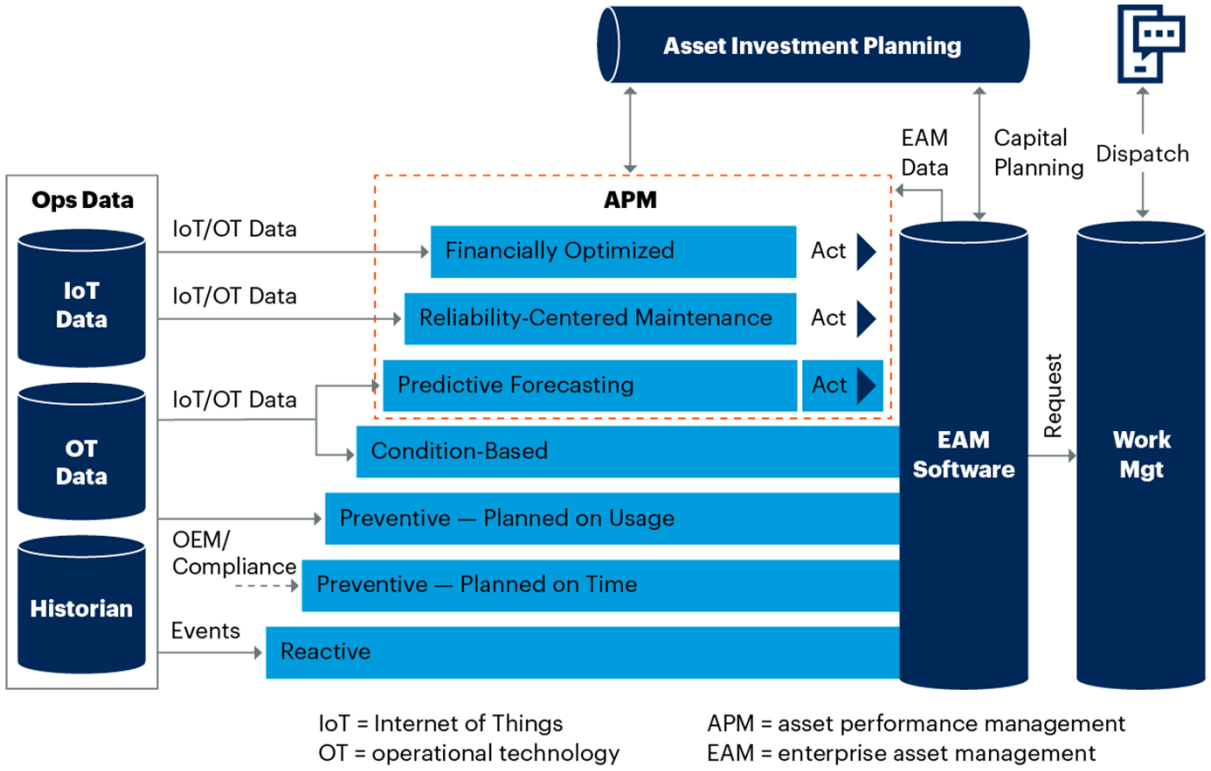
NPP Automation Evolution



Source: Smart Energy International

Asset Management Automation

Asset Management Tools Relationship



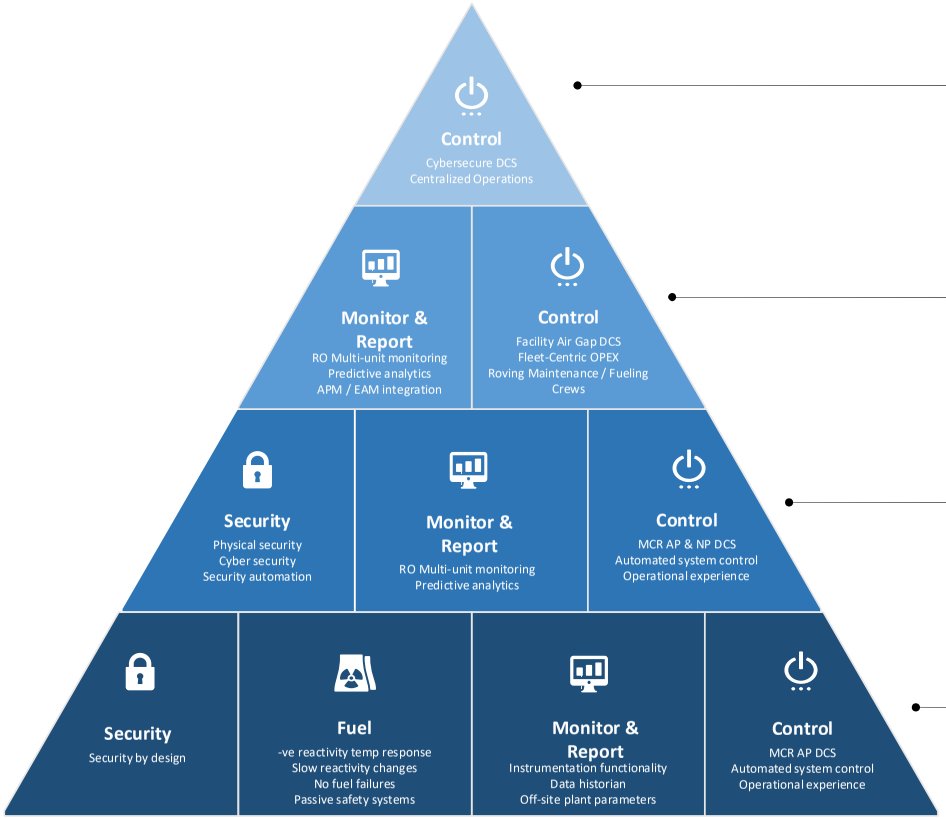


Source: Gartner
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Gartner

MMR OPERATIONAL DEMONSTRATION PHASES

Operational demonstrations to be accepted by regulatory agencies to establish next phase licensing conditions and operational conditions and demonstrations



Phase 3 – Multi-MMR Facility Off-Site Operations (Fleet)

Control: Cybersecure DCS & Central Control Centre demonstrates fully autonomous operation

Phase 2 – Multi-MMR Facility On-Site Operations (Fleet)

Monitoring: Multi-unit monitoring demonstrates 1:N+ RO per reactor, APM / EAM integration demonstrates automated component monitoring & maintenance program
Control: Air gap DCS demonstrates remote net-based control capability, fleet-centric OPEX & roving crews demonstrate central operations organization capability

Phase 1 – Demonstration Multi-MMR Facility

Security: Automated security systems demonstrate no on-site security presence
Monitoring: Multi-unit monitoring demonstrates 1:N RO per reactor, predictive analytics demonstrates AI functionality for condition-based maintenance
Control: NP & AP DCS demonstrates remote control capability; OPEX defines multi-MMR workload and demonstrates facility staffing requirements

Phase 0 – Demonstration Single-MMR Facility

Security: Deter & delay design demonstrates security staff minimization
Fuel: Fuel safety design & passive safety systems demonstrate no credited operator intervention for safety events
Monitoring: Online facility data demonstrates remote monitoring capability
Control: AP Digital Control System demonstrates remote control capability; OPEX defines 1-MMR workload and demonstrates facility staffing requirements


Q&A