INNOVATION
FOR THE FUTURE OF NUCLEAR ENERGY
A GLOBAL FORUM

Innovation for the Future of Nuclear Energy – A Global Forum

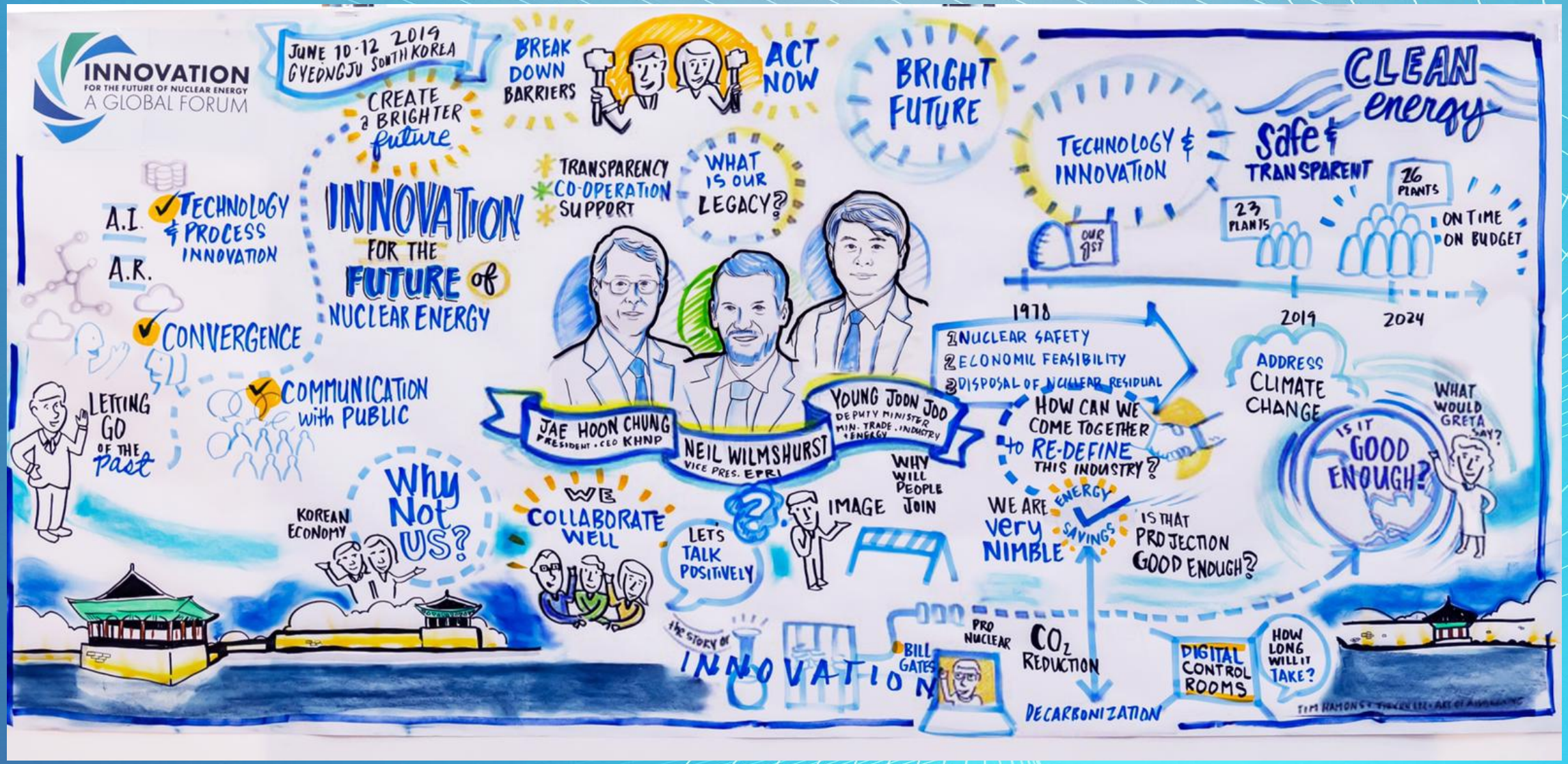
Gyeongju, Korea
June 10-12, 2019

EPRI ELECTRIC POWER RESEARCH INSTITUTE

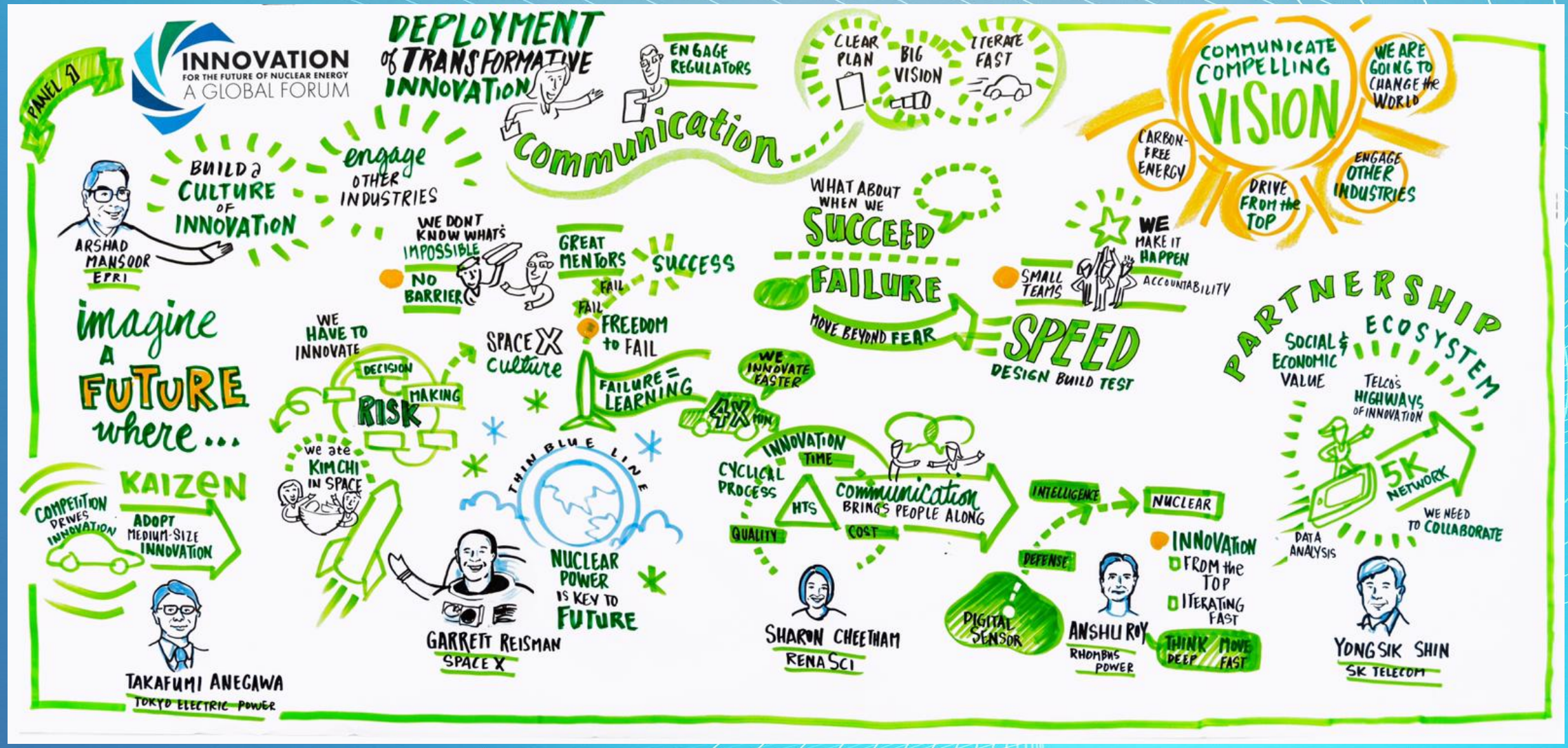
IAEA International Atomic Energy Agency

KHNP

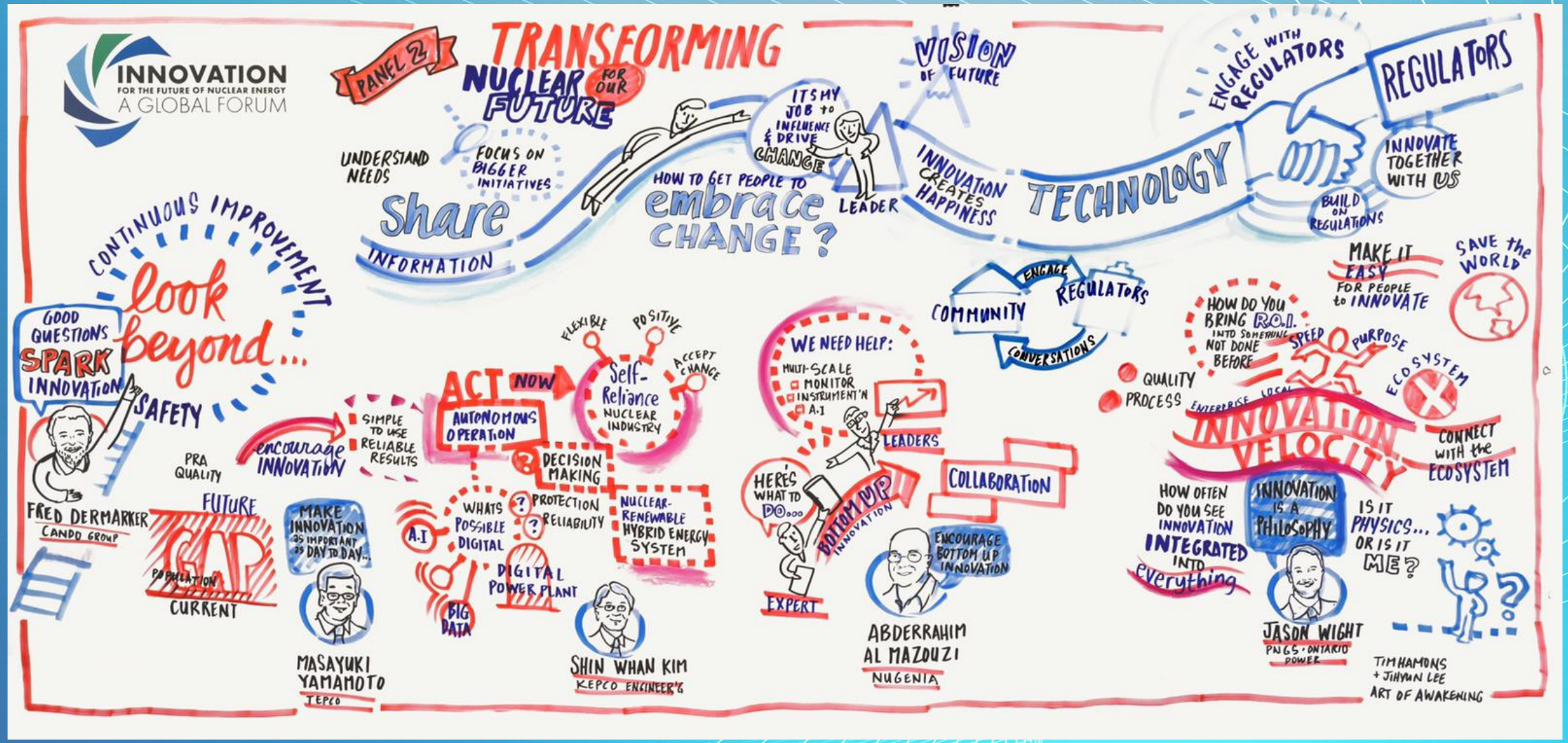
NATIONAL NUCLEAR LABORATORY



Welcome, Opening Remarks, and Keynote



Deployment of Transformative Innovation – Sharing Across Sectors



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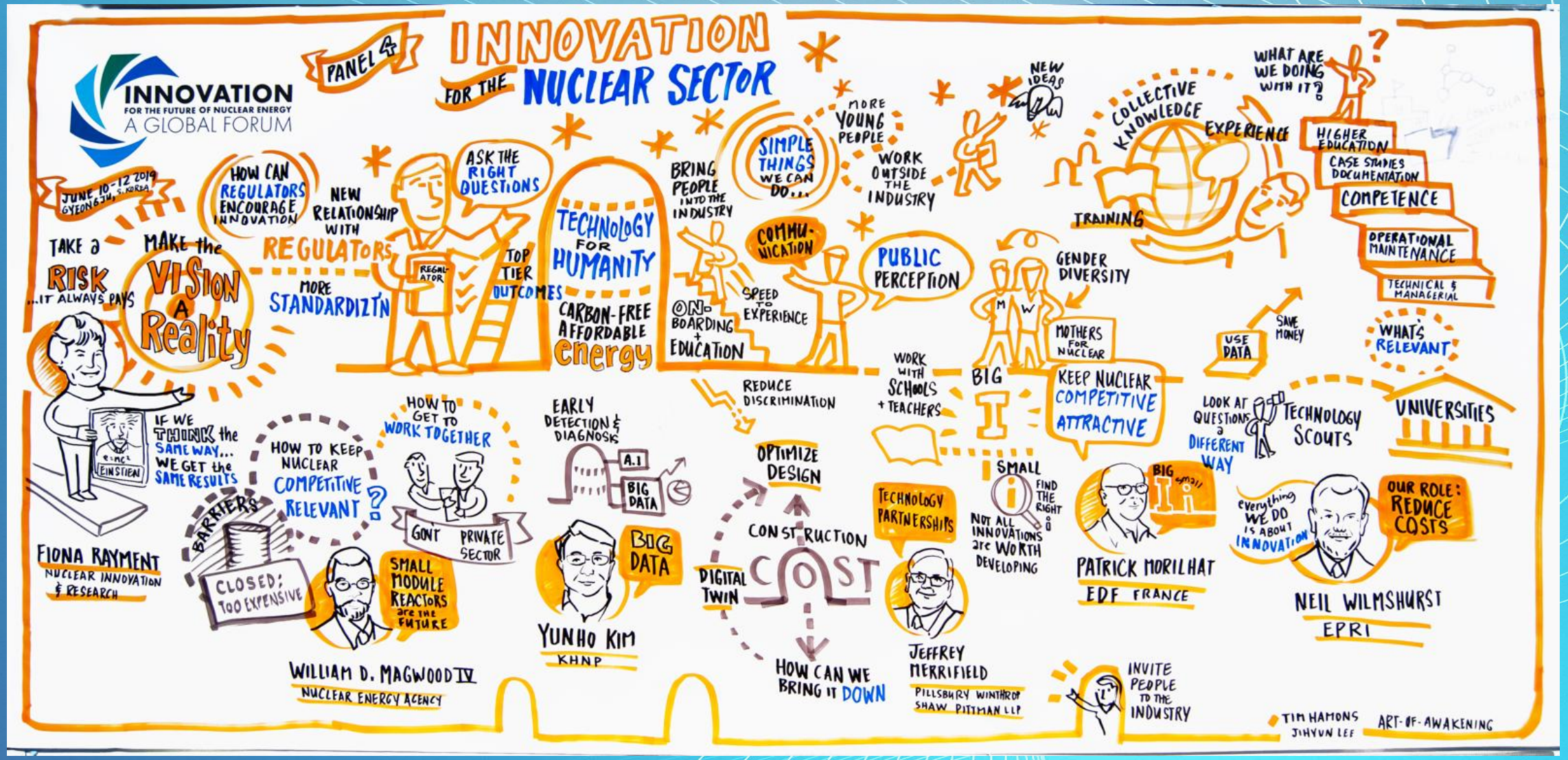
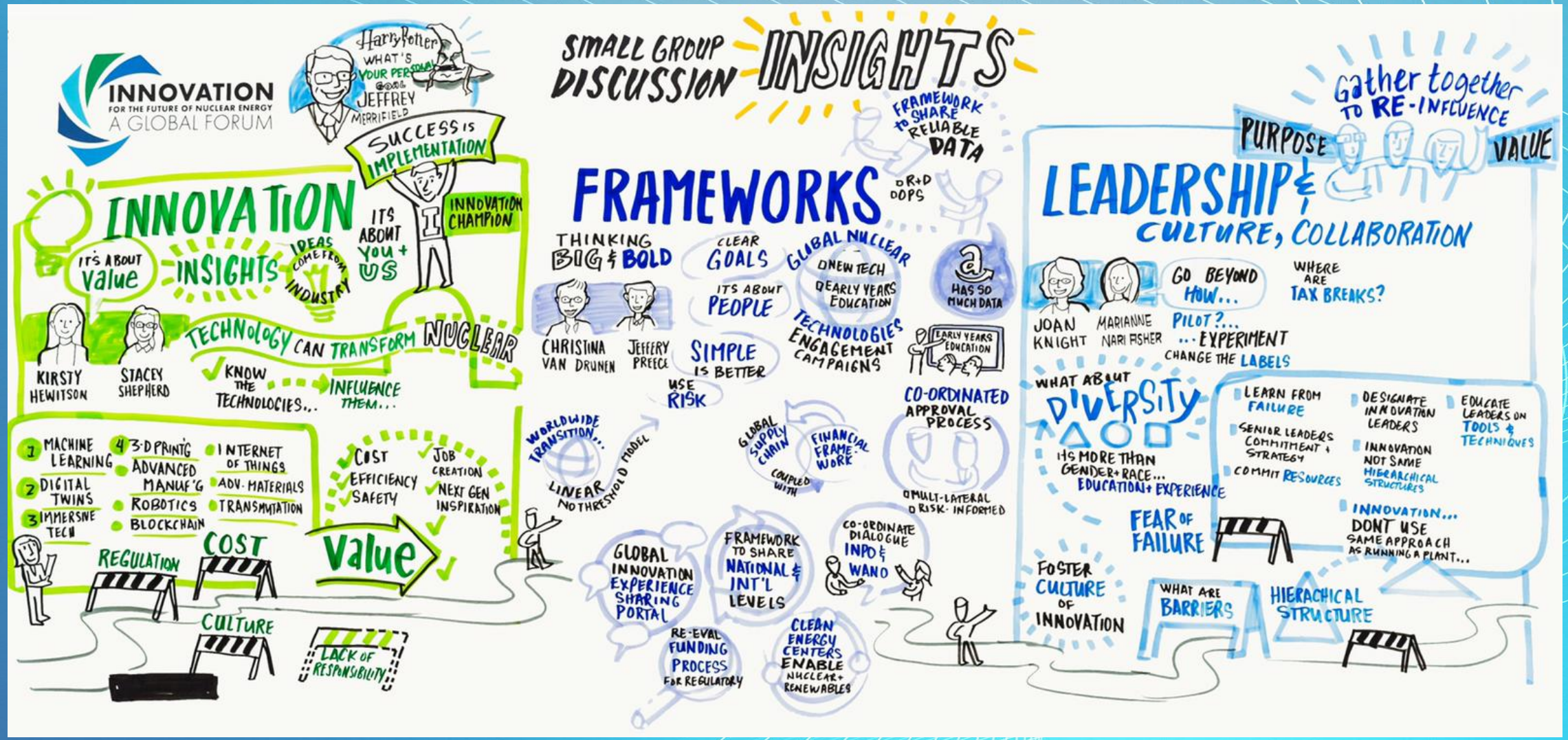
Transforming Nuclear for Our Future

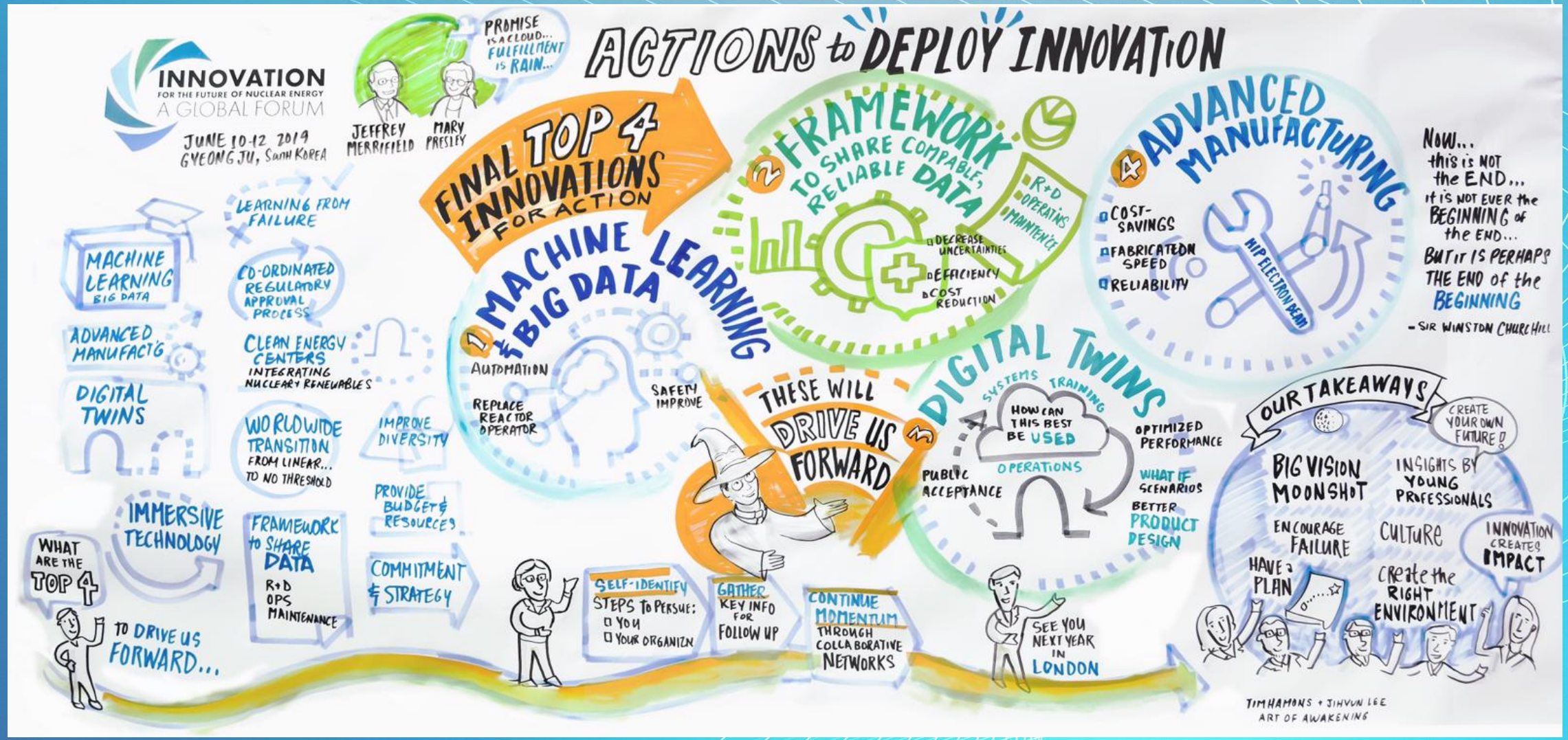


Innovation in the Nuclear Sector

Regulator Perspectives Roundtable



Small Group Discussion Insights



Actions to Deploy Innovations

Top 4 Innovations

1. **machine learning** to make better use of the 'big data' already available in the nuclear power sector for optimizing maintenance;
2. **using more innovative frameworks** for information exchange, to share data on research and development, operations and maintenance
3. **digital twinning** (the virtual recreation of a process into a computer-based model) to improve NPP performance and to reduce costs
4. **advanced manufacturing**, including 3D printing, to address supply chain challenges

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Top Innovations from Each Category

Technology	Framework	Culture and Leadership
Machine Learning / Big Data	World wide transition from the linear no-threshold model	Accepting failure. Learning from failure.
Digital Twins	Global supply chain coupled with financial framework to reduce costs and improve efficiencies	Provide budget and resources.
Immersive Technologies	Coordinated, multi-lateral risk-informed regulatory approval process	Develop commitment and strategy
Advanced Manufacturing / 3D Printing	Frameworks to share comparable, reliable data - R&D, operations, maintenance	Improve diversity

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"Now this is not the end. It is not even the **beginning** of the end. But it is, perhaps, the end of the **beginning**."

-- Sir Winston Churchill

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Top 12 Innovations

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Top 12 Innovations that Were Ranked

- Machine learning/big data
- Digital twins
- Advanced manufacturing
- Immersive technologies
- Worldwide transition from the linear no-threshold model
- Framework to share comparable, reliable data – R&D, operations, maintenance
- Clean Energy Centers integrating nuclear and renewables
- Coordinated, multi-lateral risk-informed regulatory approval process
- Accepting / Learning from Failure
- Develop Commitment and Strategy
- Provide Budget, Resources
- Improve Diversity

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Machine learning/big data

Examples:

- Replace reactor operator
- Automation of processes
- Predictive maintenance
- Guiding regulatory inspections

- Key Benefits:
  - Operator efficiency
  - Safety improvement
  - Improved reliability
  - Cost savings
- Technology Readiness:
  - High – Technology mature and used in other industries
- Key Stakeholders:
  - Supply chain
  - Regulator
  - Plant operator
  - Vendor

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Digital twins

Examples:

- Plant/sub-components/systems
- Fuel and waste casks
- Operating parameters
- Training/education applications

- Key Benefits:
  - Operational efficiency
  - Safety improvement
  - Cost savings
  - Public acceptance
  - Improved reliability
- Technology Readiness:
  - Medium – Technology ready for first use
  - High – Technology mature and used in other industries
- Key Stakeholders:
  - Supply chain
  - Regulator
  - Plant operator
  - Vendor

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Advanced manufacturing

Examples:

- HIP
- Electron beam welding
- Component modularization and standardization

- Key Benefits:
  - Cost savings
  - Reduced inspections e.g. no welds
  - Fabrication speed
  - Reliability
- Technology Readiness:
  - Medium – Technology ready for first use
  - High – Technology mature and used in other industries
- Key Stakeholders:
  - Regulator
  - Plant operator
  - Vendor
  - Supply chain

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Immersive technologies

Virtual reality, augmented reality

Examples:

- Maintenance
- Training
- Design validation

- Key Benefits:
  - Improved engagement – fun!
  - Cost savings
  - Improved communication/knowledge transfer
  - Environmental impact (less travel)
- Technology Readiness:
  - High – Technology mature and used in other industries
- Key Stakeholders:
  - Supply chain
  - Regulator
  - Plant operator

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Worldwide transition from LNT model

- Endorsed by the World Health Organization
- Right-size emergency zones and precautionary actions

- Key Benefits:
  - Operational efficiency / cost reduction
  - Safety Improvement
  - Enhance public trust
- Technology Readiness:
  - Medium – Framework developed with few use cases
- Key Stakeholders:
  - Legislator
  - Regulator
  - Utility
  - Vendor
  - Research Organizations

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Framework to share comparable, reliable data – R&D, operations, maintenance

- Builds international database of operating data to enable AI and advanced analytics
- Optimizes operations and maintenance
- Decreases uncertainties in risk assessment

- Key Benefits:
  - Operational efficiency / cost reduction
  - Safety Improvement
- Technology Readiness:
  - Medium – Framework developed with few use cases
- Key Stakeholders:
  - Regulator
  - Utility
  - Vendor
  - Research Organizations
  - International organizations

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Clean Energy Centers integrating nuclear and renewables

- Positions nuclear as a clean-energy enabler in public perception
- Advances integrated energy systems
- Sustains nuclear technology as an option

- Key Benefits:
  - Enhance public trust
- Technology Readiness:
  - High – Framework well developed and used broadly in other industries
- Key Stakeholders:
  - Utility, grid operator
  - Vendor
  - Research Organizations

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Coordinated, multi-lateral, risk-informed regulatory approval process

- Increases regulatory certainty in export markets to underpin business case and financing
- Accelerates global deployment of innovations

- Key Benefits:
  - Operational efficiency / cost reduction
  - Enhance public trust
  - Regulatory efficiency
- Technology Readiness:
  - Low – Conceptual Framework
- Key Stakeholders:
  - Regulator
  - Utility
  - Vendor
  - Research Organizations
  - International organizations

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Accepting / Learning from Failure

- Success for this innovation is to change behaviour and recognize that innovation involves learning from failures. Leaders expect some failures in innovation.

- Key Benefits:
  - Deploy innovations more effectively or faster
  - Reduce cost / increase efficiency
  - Ability to attract and retain top talent
- Organizational Readiness:
  - Low – May need substantial shifts in culture, organizations or relationships; Resistance expected
- Key Stakeholders:
  - Regulator
  - Utility
  - Vendor
  - Research Organizations

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Develop Commitment and Strategy

- Success for this innovation is for employees to understand the importance of innovation and where to focus their innovation efforts.

- Key Benefits:
  - More diverse set of views (stimulate innovation)
  - Deploy innovations more effectively or faster
  - Enhanced safety / reduced uncertainty
  - Reduce cost / increase efficiency
  - Forward-looking industry leadership
  - Ability to attract and retain top talent
- Organizational Readiness:
  - Medium – May need moderate shifts in culture, organizations or relationships; Willingness is country-specific
  - High – Small changes to existing culture, organizations or relationships; Strong willingness for change globally
- Key Stakeholders:
  - Regulator
  - Utility
  - Vendor
  - Research Organizations

Provide Budget, Resources

- Success for this innovation is to provide adequate space and tools for innovation to be pursued such that innovators are energized.

- Key Benefits:
  - More diverse set of views (stimulate innovation)
  - Deploy innovations more effectively or faster
  - Enhanced safety / reduced uncertainty
  - Reduce cost / increase efficiency
  - Forward-looking industry leadership
  - Ability to attract and retain top talent
- Organizational Readiness:
  - Medium – May need moderate shifts in culture, organizations or relationships; Willingness is country-specific
- Key Stakeholders:
  - Legislator
  - Regulator
  - Utility
  - Vendor
  - Research Organizations

Improve Diversity

- Success for this innovation is to extend diversity to experiences and educational background, especially in recruitment practices and team building.

- Key Benefits:
  - More diverse set of views (stimulate innovation)
  - Reduce cost / increase efficiency
  - Forward-looking industry leadership
  - Ability to attract and retain top talent
- Organizational Readiness:
  - High – Small changes to existing culture, organizations or relationships; Strong willingness for change globally
- Key Stakeholders:
  - Legislator
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  - Research Organizations

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Lists of All 28 Innovations

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Innovations - Technology

- Machine learning/big data
- Digital twins
- Immersive technologies
- 3D printing
- Advanced manufacturing
- Robotics
- Blockchain
- Internet of Things
- Advanced materials
- Transmutation

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How can **frameworks** that help boost innovation be designed?

1. Worldwide transition from the linear no-threshold model
2. Global supply chain coupled with financial framework to reduce costs and improve efficiencies
3. Coordinated, multi-lateral risk-informed regulatory approval process
4. Framework to share comparable, reliable data – R&D, operations, maintenance
5. Coordinated, global nuclear technology public engagement campaign, including early-years education and new technologies
6. Global innovation sharing portal
7. Framework to share the risk of innovations at national and international levels
8. Consider opportunities to coordinate/enhance dialogue between INPO/WANO and safety authorities
9. Budgetary funding process for nuclear regulatory organizations (US/Canada)
10. Clean Energy Centers integrating nuclear and renewables

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Innovations – Culture, Leadership & Collaboration

1. Foster an organizational culture of accepting and learning from failure [**culture**]
2. Leaders should grant sufficient time, budget, and resources for workers to innovate [**culture/leadership**]
3. Senior Leaders should develop a high-level commitment and strategy for innovation [**leadership**]
4. Designate 'innovation leaders' in the organization that report to institutional leadership or utilize dedicated teams that pursue innovative projects with clear scope [**leadership**]
5. Innovation activities should not be subject to the same hierarchical structure as operations [**leadership**]
6. Educate leaders on techniques and tools for leading innovation – leaders to set the stage, not have all the answers [**leadership**]
7. Improve on diversity beyond the traditional sense, including diversity of thought, experience & education [**collaboration**]
8. More effectively utilize information sharing platforms to accomplish shared objectives between institutions and international organizations [**collaboration**]

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