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Risk at the Center

Risk assessment as the cornerstone of nuclear regulation and design decisions under modernized regulatory frameworks

Battelle Energy Alliance manages INL for the
U.S. Department of Energy's Office of Nuclear Energy

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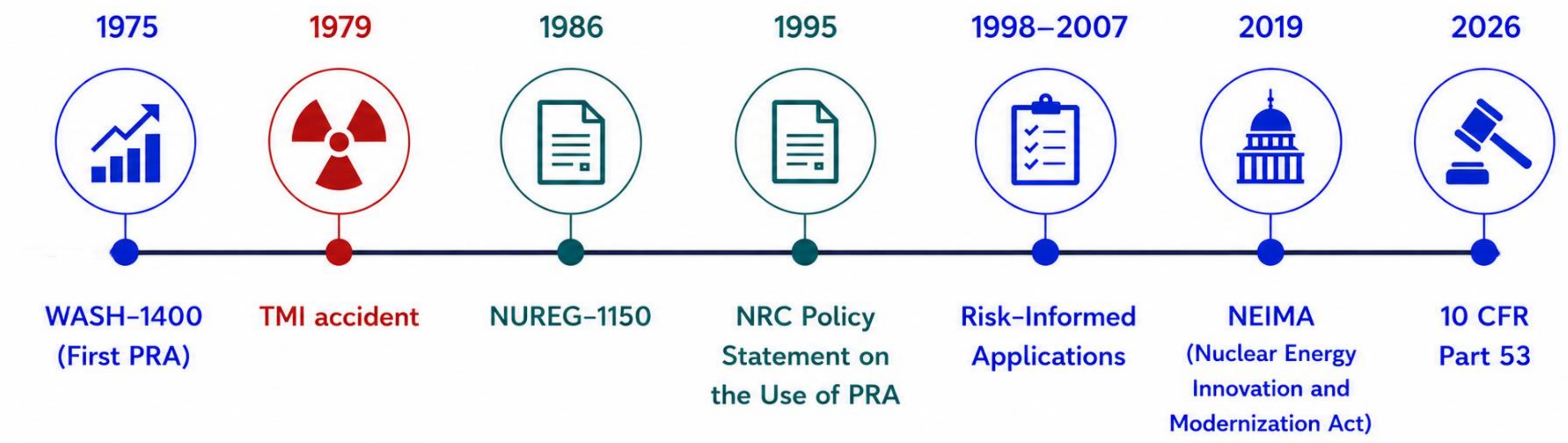
U.S.A. Nuclear Regulations – Evolution Timeline

From deterministic to risk-informed performance-based regulation

- **A 50-year journey**
  - **1974-75:** WASH-1400, The Reactor Safety Study. Quantifies nuclear risk for the first time, PRA discipline is born.
  - **1979:** Three Miles Island accident – the wake-up call
  - **1986:** NRC conducts detailed PRAs for five operating reactors; revealed insights not available from deterministic assessments (CCF and external events dominate risk)
  - **1995:** NRC formally endorses risk-informed regulation as a supporting decision-making tool
  - **1998 - 2007:** NRC approves a set of narrow risk-informed programs (RI-ISI, SSC Categorization, risk-informed surveillance frequency and technical specifications), a piecemeal progress
  - **2004 – 2012:** Advanced reactor licensing hits the wall
  - **2019:** Nuclear Energy Innovation and Modernization Act (NEIMA) enacted directing NRC to develop technology-inclusive, performance-based licensing framework for advanced reactors recognizing inadequacy of Part 50 for advanced reactors requesting a risk-informed alternative
  - **2026:** 10 CFR Part 53 is issued



Part 50 / 52 – Risk is an Afterthought

- Deterministic rules are **the law**
  - Prescriptive DBAs and GDCs are "set in stone"
  - Design is prescribed
- Risk is an afterthought
- Role of PRA
  - Limited exemptions from specific requirements

A plant that complied with all Part 50 requirements was deemed safe, regardless of what its PRA showed about actual risk level.

Prescriptive DBAs & GDCs → Design to comply with DBAs & GDCs → Regulatory Approval

PRA – a tool to exempt some requirements

GDCs – general design criteria
DBAs – design basis accidents
RI-ISI – risk-informed inservice inspection
SSC – structures, systems, and components
TS - technical specifications

WHAT PRA **COULD** DO UNDER PART 50

- ✓ Justify a single exemption request
- ✓ Support RI-ISI programs (reduced inspections)
- ✓ Categorize SSCs under 10 CFR 50.69
- ✓ Implement RI surveillance and TS programs

WHAT PRA **COULD NOT** DO UNDER PART 50

- × Replace or remove a GDC requirement
- × Redefine the Design Basis Accident prescribed list
- × Serve as the primary means for safety demonstration
- × Support system design and architecture decisions

Part 53 Changes Everything!

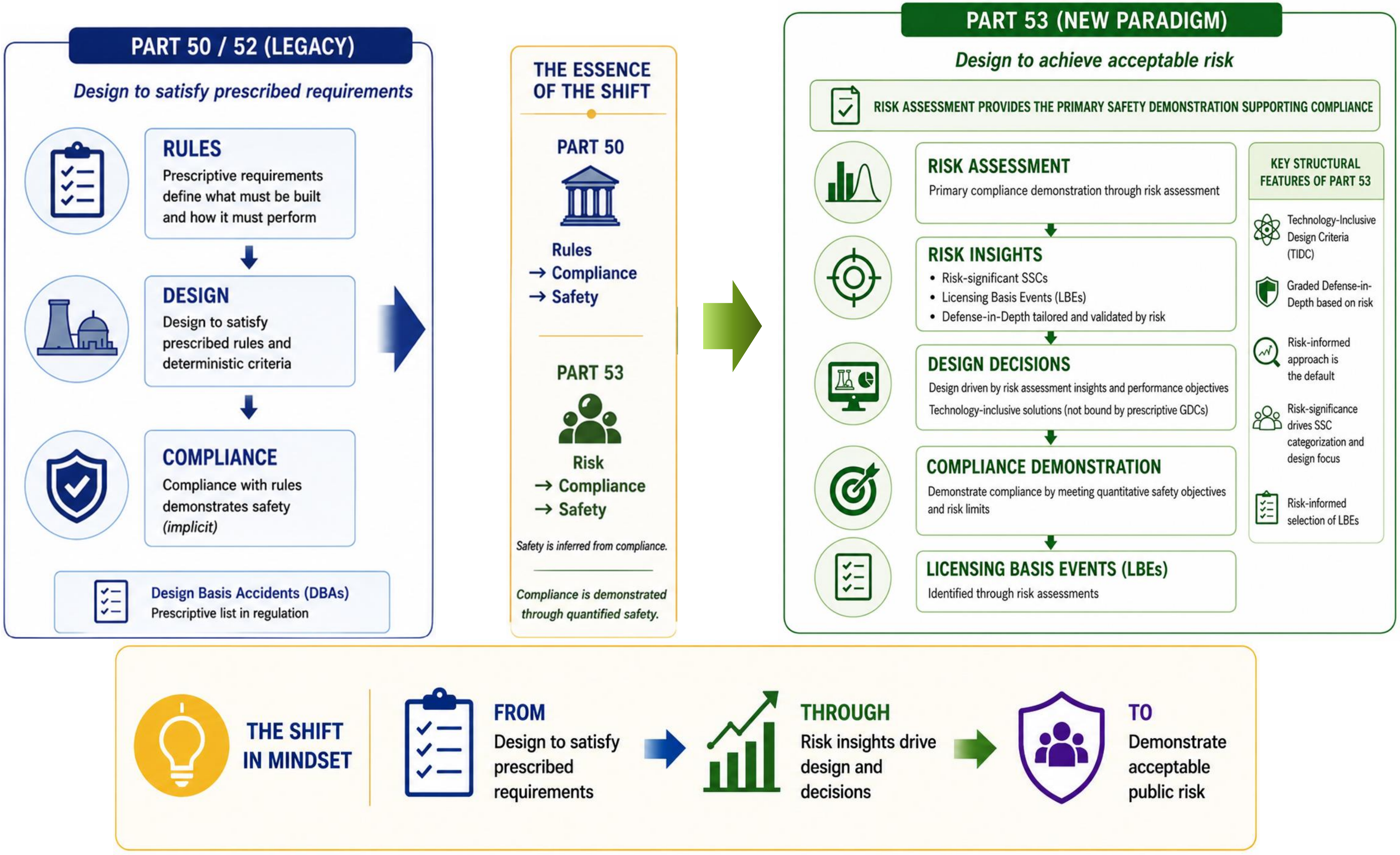
Safety is no longer inferred from compliance

Safety is demonstrated through a systematic risk assessment

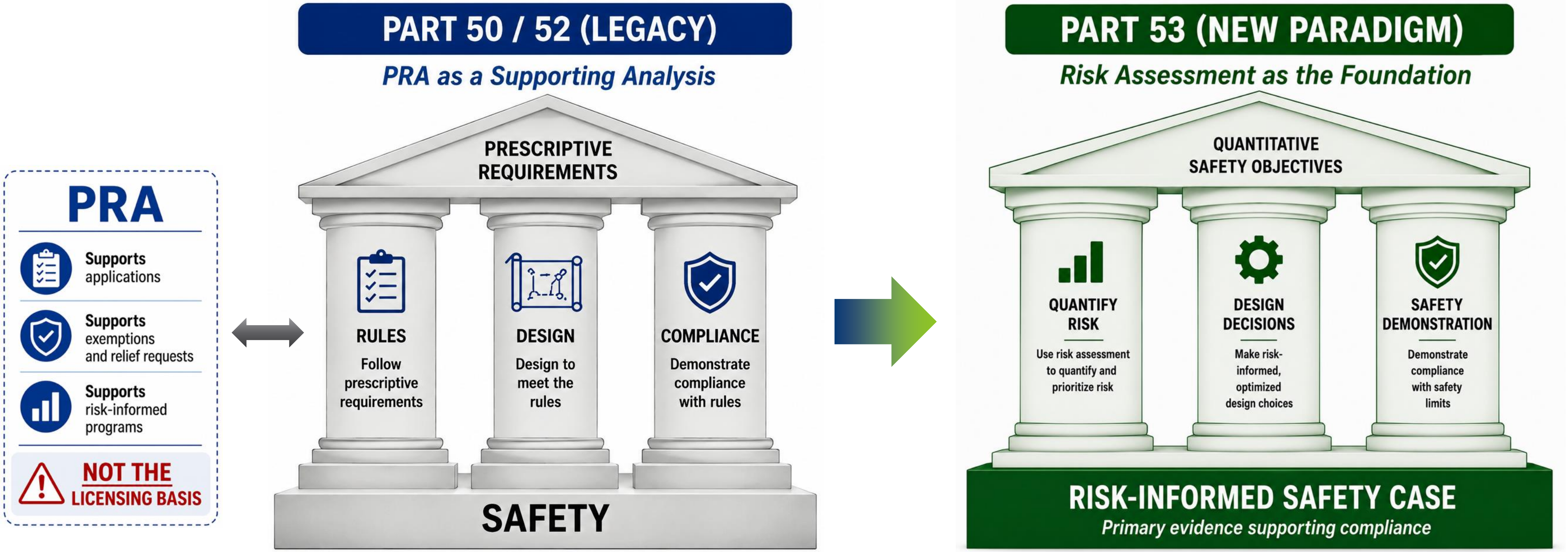
with quantified risks and objective performance metrics

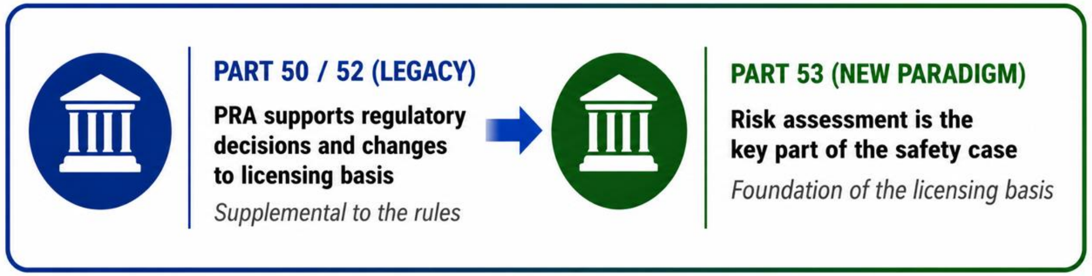
Part 53 – Safety Philosophy Shift

CDF – Core Damage Frequency;
LERF – Large Early Release Frequency;
QHO – Quantitative Health Objective;
DBE – Design Basis Events;
BDBE – Beyond Design Basis Events;
SSC - Systems, Structures, and Components



The Role of Risk: Part 50 vs. Part 53

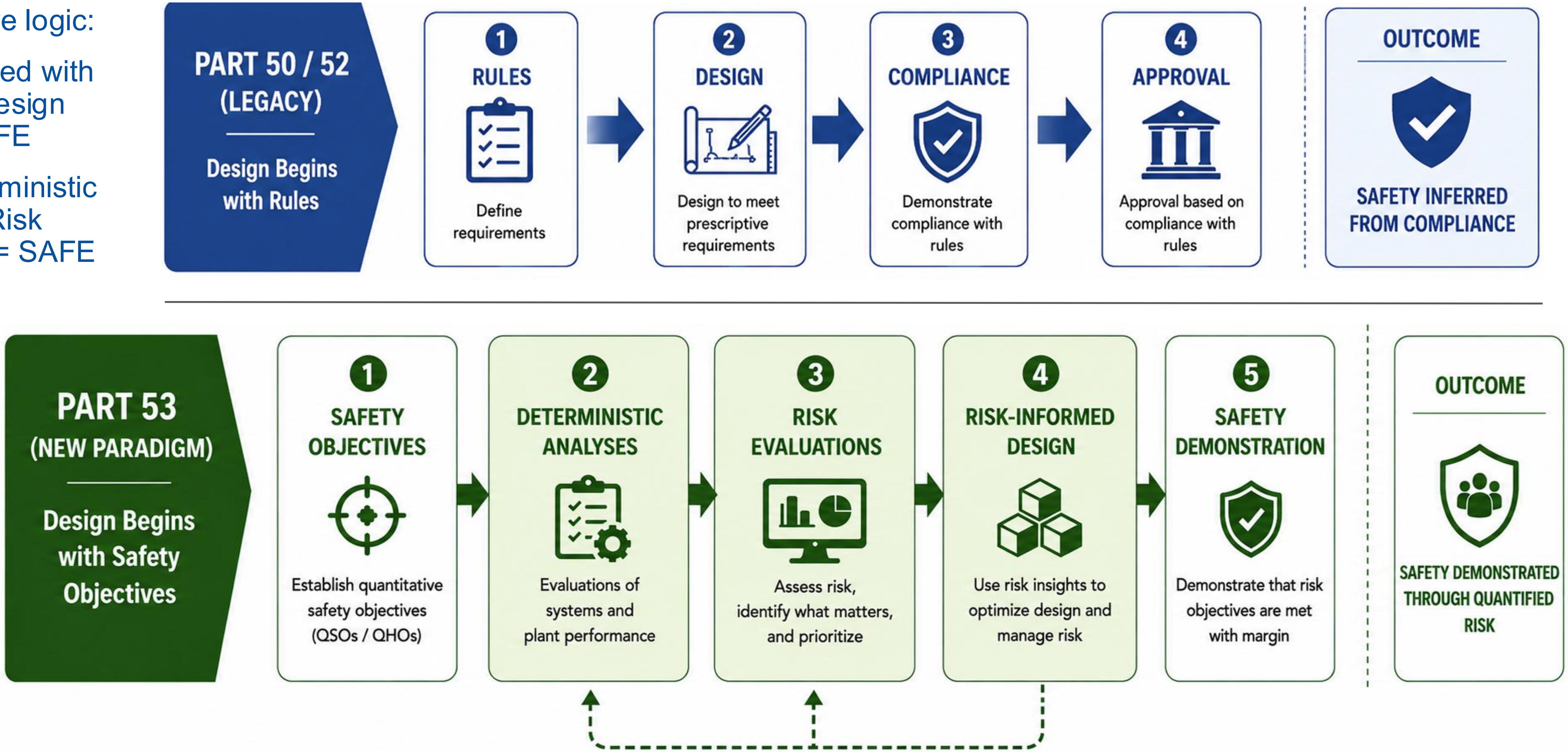




- Under Part 50, PRA supports compliance and a few exemptions
- Under Part 53, **risk assessment** becomes the primary evidence supporting licensing and compliance

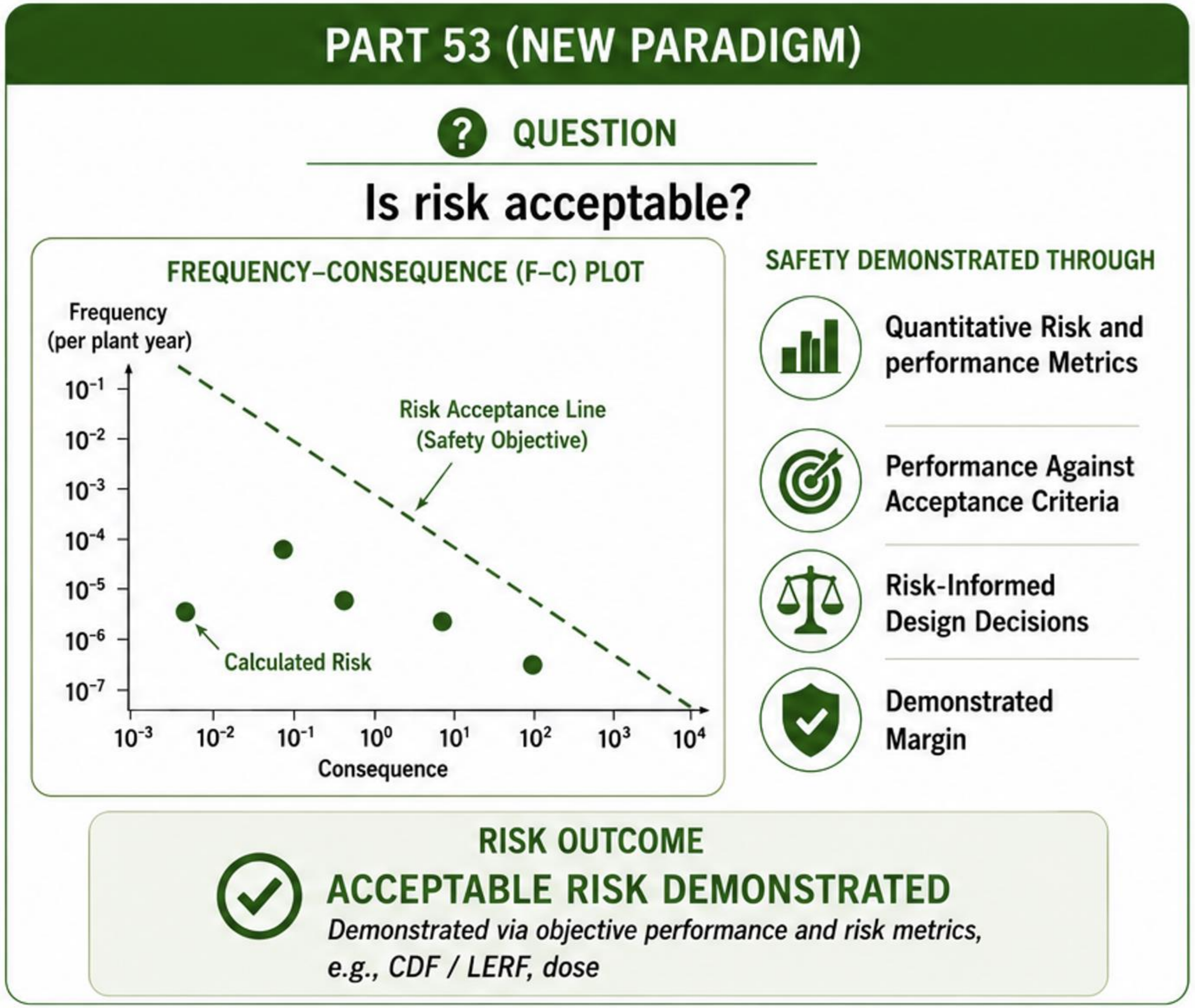
Safety Logic under Two Rules

- Let's compare logic:
- **Old** – complied with prescribed design criteria = SAFE
- **New** – Deterministic Analyses + Risk Evaluations = SAFE



What Defines “Safe”?

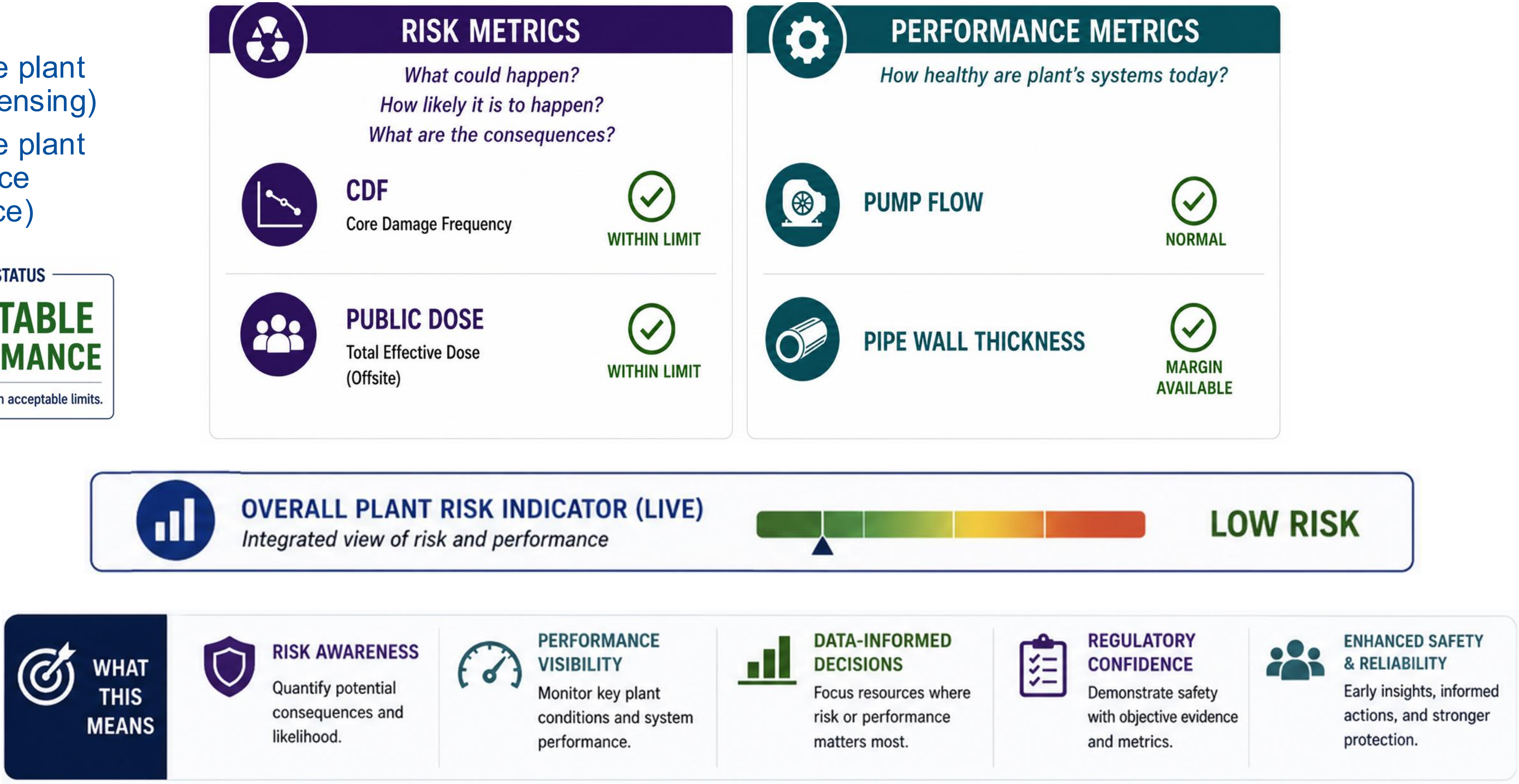
VS



- “**Safe**” is no longer defined by compliance alone, but though demonstrate performance and resulting risk

Quantified Risk Metrics

- Goals:
  - Acceptable plant design (licensing)
  - Acceptable plant performance (compliance)



Licensing Basis Events Development Process

- Progressive
- Iterative
- Requires integration of many disciplines and teams

Systems Classification based on Risk Significance

Process is:

- Objective-focused
  - Ensure design and performance to achieve and maintain safety objectives
- Graded
  - Regulatory rigor and oversight are commensurate with risk significance
- Risk-informed
- Data and evidence-based

RISK SIGNIFICANCE (Contribution to Risk)	SAFETY CATEGORIZATION	DEFINITION	REGULATORY TREATMENT & REQUIREMENTS
HIGHER RISK	SAFETY-RELATED (SR)	SSCs that are relied upon to remain functional during and following design-basis accidents (DBA) to ensure the plant meets safety criteria.	**Strict Regulatory Oversight** • Compliance with Quality Assurance programs • Qualification for specific service conditions over design life • Use of industry codes and standards
	NON-SAFETY-RELATED BUT SAFETY SIGNIFICANT (NSRSS)	SSCs not relied upon to meet DBA scenarios, but relied upon as part of defense-in-depth measures or for risk-significant functions identified by PRA.	**Require special treatments tailored to SSC's safety significance** • Material qualification • Appropriate programmatic controls • Targeted quality assurance measures
LOWER RISK	NON-SAFETY-SIGNIFICANT (NSS)	SSCs that are not SR or NSRSS, are not relied on to achieve adequate defense in depth or to perform risk-significant functions.	**Minimal to no special treatment rules** • Standard, commercial-grade construction approaches and codes • Must still demonstrate failure would not adversely affect SR and NSRSS systems

Risk at the Center

Risk assessment is the **cornerstone** of safety decisions under modernized regulatory framework *exemplified by Part 53*

UNDERSTAND RISKS
Identify what matters

MAKE INFORMED DECISIONS
Focus resources on what matters

DELIVER GREATER VALUE
Adequate Safety. Optimized Performance. Improved Economics.

PART 53 DOES NOT PRESCRIBE A SINGLE RISK ASSESSMENT METHOD

Probabilistic Risk Assessment (PRA)

- Well-developed and mature
- Comprehensive and rigorous
- Adopted by industry

Systematic Risk Evacuations (SREs)

- Tailored to the scope & complexity
- Flexible and focused
- Useful when PRA is not practical

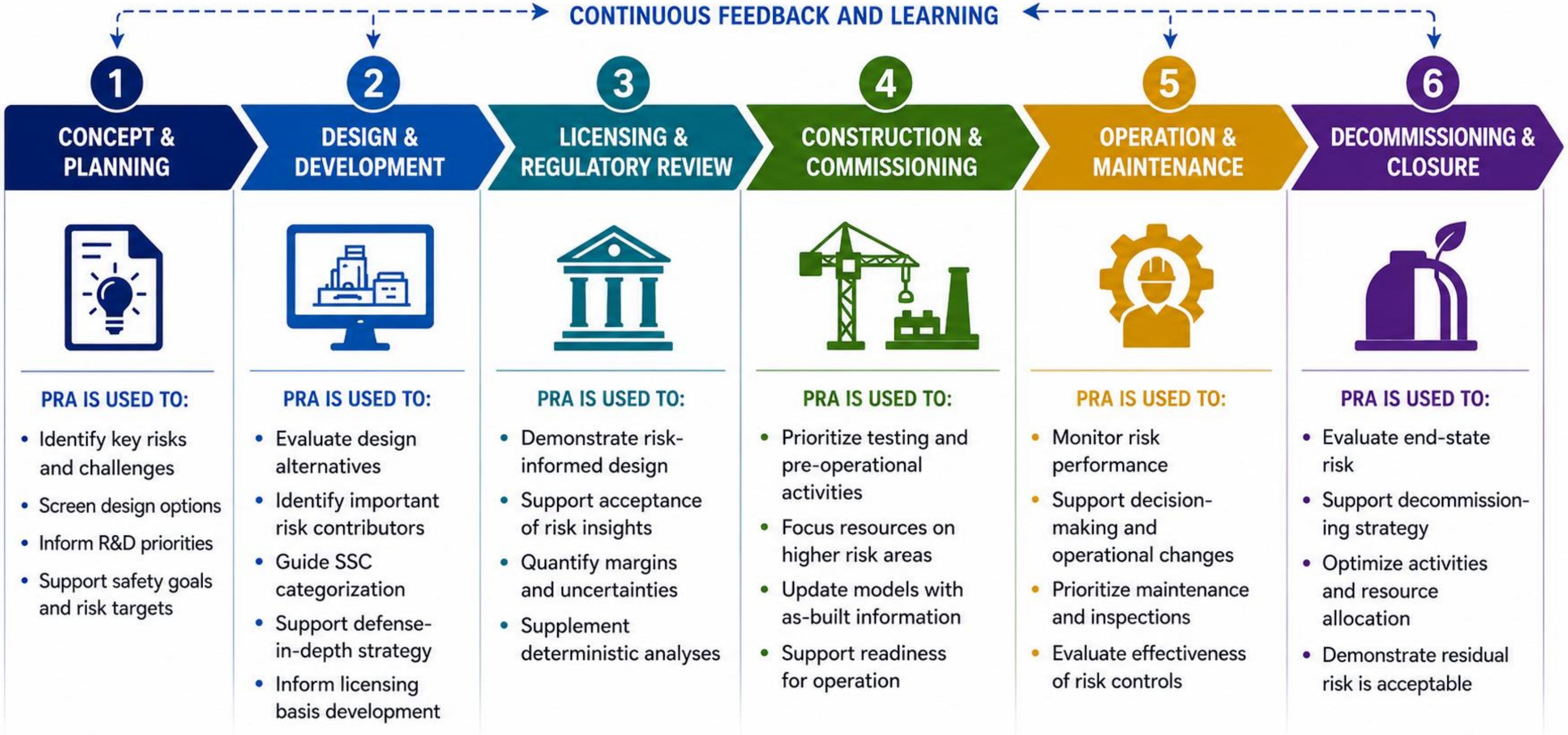
Appropriate Combinations of PRA and SRE

- Leverages strengths of both approaches

PRA IS A PROVEN APPROACH to evaluate risk and is the **most mature, comprehensive, and widely demonstrated** risk assessment method available today

PRA Across Lifecycle

One tool. Many Applications. Continuous Risk Insights.



- PRA delivers value throughout the entire lifecycle:
  - Design support
  - Regulatory confidence
  - Efficient use of resources by focusing on risk-significant systems
  - Continuous improvements

RESULT:

- Risk-informed decisions at every stage lead to safer designs, improved economics of new plants, and more effective and efficient operations

PRA for Optimization of Design

DESIGN EVOLVES. PRA PROVIDES CONTINUOUS INSIGHT.

Concept → Preliminary Design → Detailed Design → Construction → Operation

← PRA continuously improves the design as knowledge grows →

HOW PRA INFORMS AND OPTIMIZES DESIGN

1 DEFINE DESIGN OBJECTIVES

- Clarify safety goals and performance objectives
- Identify functional and regulatory requirements
- Establish decision criteria and constraints

2 IDENTIFY AND UNDERSTAND RISKS

- Use PRA to identify potential scenarios and failure modes
- Quantify risk significance (frequency and consequence)
- Determine key risk drivers and contributors

3 EVALUATE DESIGN ALTERNATIVES

- Develop and screen feasible alternatives
- Evaluate impact on risk (reduction potential)
- Assess technical feasibility, cost, and operability

4 OPTIMIZE THE DESIGN

- Compare alternatives
- Maximize safety benefit per dollar
- Eliminate unnecessary complexity and over-design
- Invest resources where risk reduction is greatest

5 SELECT THE PREFERRED DESIGN

- Select the optimal solution
- Document the risk basis for the decision
- Ensure transparency and traceability

6 VALIDATE, IMPLEMENT, AND UPDATE

- Implement the design decision
- Monitor performance and actual risk
- Update PRA and refine as new information emerges

The objective is not highest-as-possible safety or low-as-possible risk.

THE OBJECTIVE IS THE OPTIMUM DESIGN THAT DELIVERS THE REQUIRED SAFETY WITH THE GREATEST VALUE.

RIGHT-SIZE SAFETY SYSTEMS
Right level of protection to meet safety objectives.

REDUCE NUMBER OF SAFETY-RELATED SSCs
Remove low-value complexity and cost.

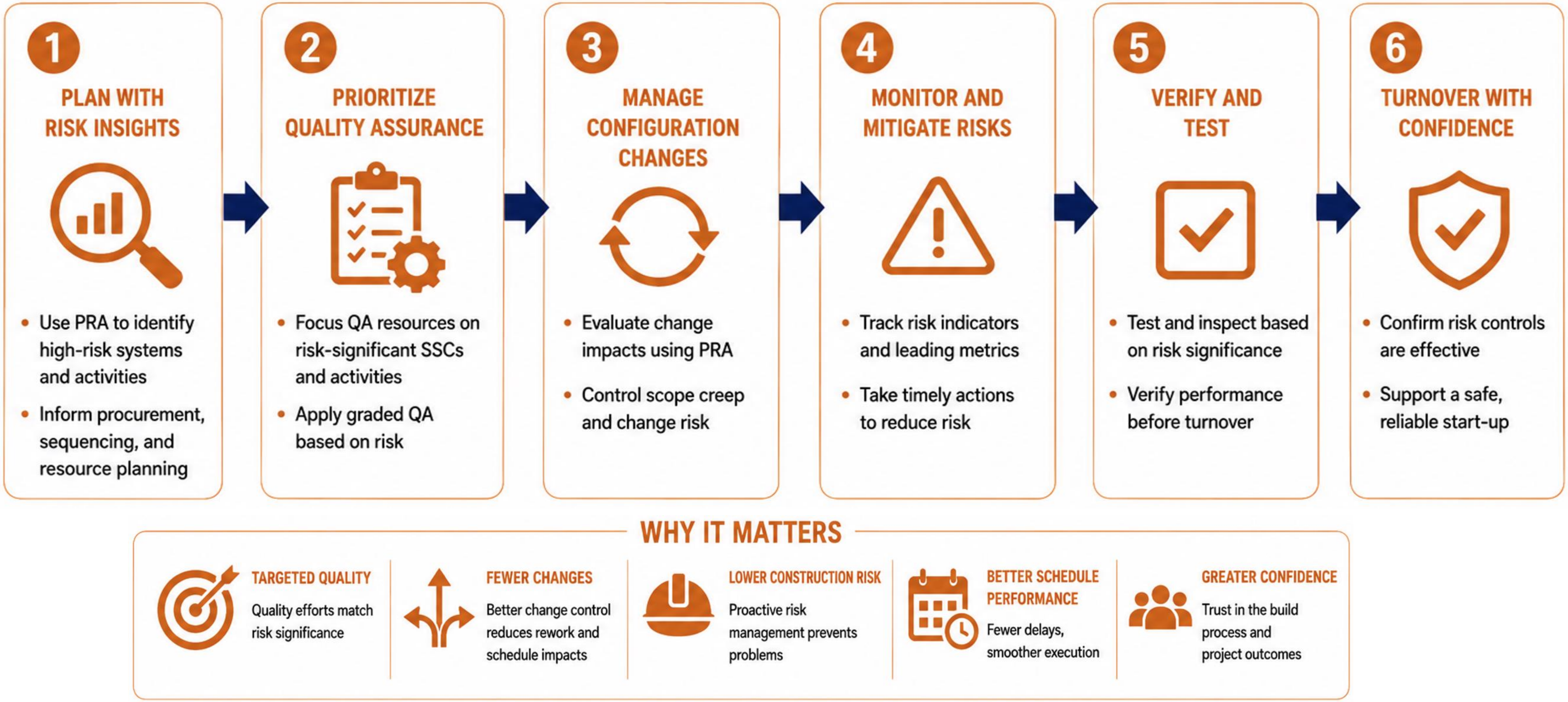
IMPROVE CONSTRUCTABILITY
Simplify design and reduce integration risk.

REDUCE LIFE-CYCLE COST
Lower capital and operating costs over the plant life.

SIMPLIFY LICENSING
Clear, defensible risk basis speeds regulatory review.

PRA to Strengthen Licensing

PRA to Improve Construction



PRA to Optimize Plant Operations

1 UNDERSTAND OPERATIONAL RISKS
- Use PRA to identify operational risks and contributors
- Monitor risk indicators

2 PLAN AND PRIORITIZE WORK
- Prioritize work based on risk significance
- Optimize resources and scheduling

3 ENABLE ONLINE MAINTENANCE
- Use PRA to evaluate technical feasibility and risk
- Perform maintenance with acceptable risk

4 PLAN RISK-INFORMED OUTAGES
- Focus outage scope on risk-significant items
- Reduce outage duration and cost

5 OPTIMIZE SURVEILLANCE
- Adjust test intervals using risk insights
- Reduce unnecessary testing

6 SUPPORT OPERATIONAL DECISIONS
- Provide real-time risk perspective
- Support procedure and plant decisions

WHY IT MATTERS

MAINTAIN SAFETY MARGINS
Protect what matters most

INCREASE EFFICIENCY
Do the right work at the right time

REDUCE OUTAGE DURATIONS
Less time offline, more value

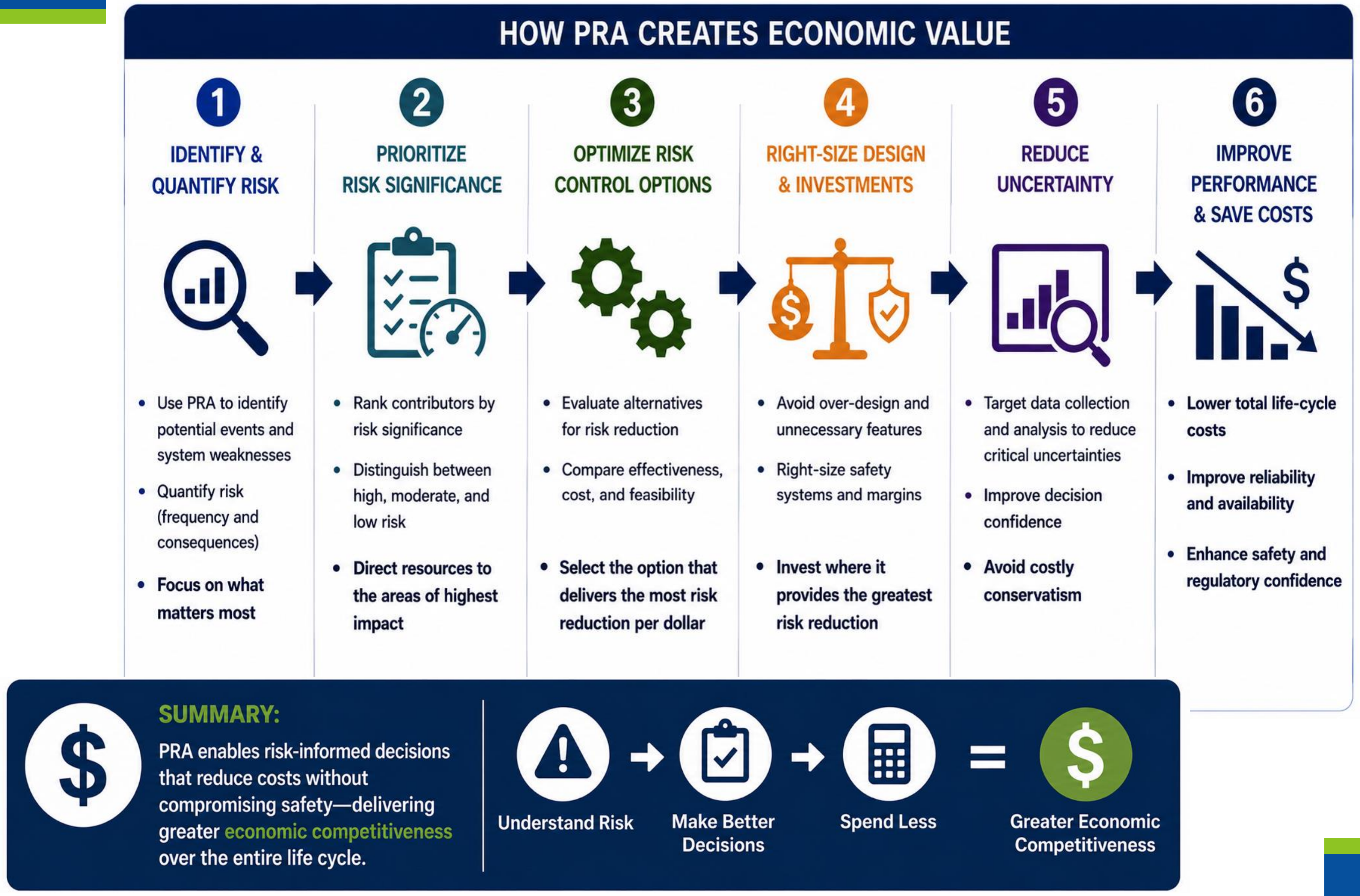
LOWER OPERATING COSTS
Smarter activities, optimized resources

BETTER DECISION SUPPORT
Timely, informed, confident decisions

PRA as a Living Tool

Economic Value of PRA

Invest in PRA early→ Save throughout the entire plant life cycle



PART 50

Risk supporting regulations

PART 53

Regulation is BUILT around risk

This is the biggest opportunity for
risk professionals in decades!

Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy. INL is the nation's center for nuclear energy research and development, and also performs research in each of DOE's strategic goal areas: energy, national security, science and the environment.