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Towards Practical Fusion Energy - Engineering Challenges and Development Strategies by the Perspective of CNPE

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ABSTRACT

- There are five critical dimensions in fusion reactor engineering: ①safety regulatory systems; ②design and engineering management; ③project implementation practices; ④industrial supply chain cultivation; ⑤standardization framework.
- Development strategies: leveraging organizational strengths to advance fusion energy development, formulating fusion regulatory policies that balance safety and development, fostering public-private collaboration to cultivate the fusion industry chain, and establishing a top-down design approach for building the fusion standardization system.

BACKGROUND

- Breakthroughs in nuclear fusion technology poised to revolutionize energy production and generate substantial economic benefits, emerging as a key medium-to-long-term development focus in global science, technology, and energy domain.
- The current research on controlled nuclear fusion is transitioning from scientific experiments to engineering practice.
- The main forces of China's fusion industry include 2 research institutes (SWIP and ASIPP), 3 leading nuclear power EPC companies (CNNC, CGN, and SPIC), as well as a series of universities and innovative enterprises.

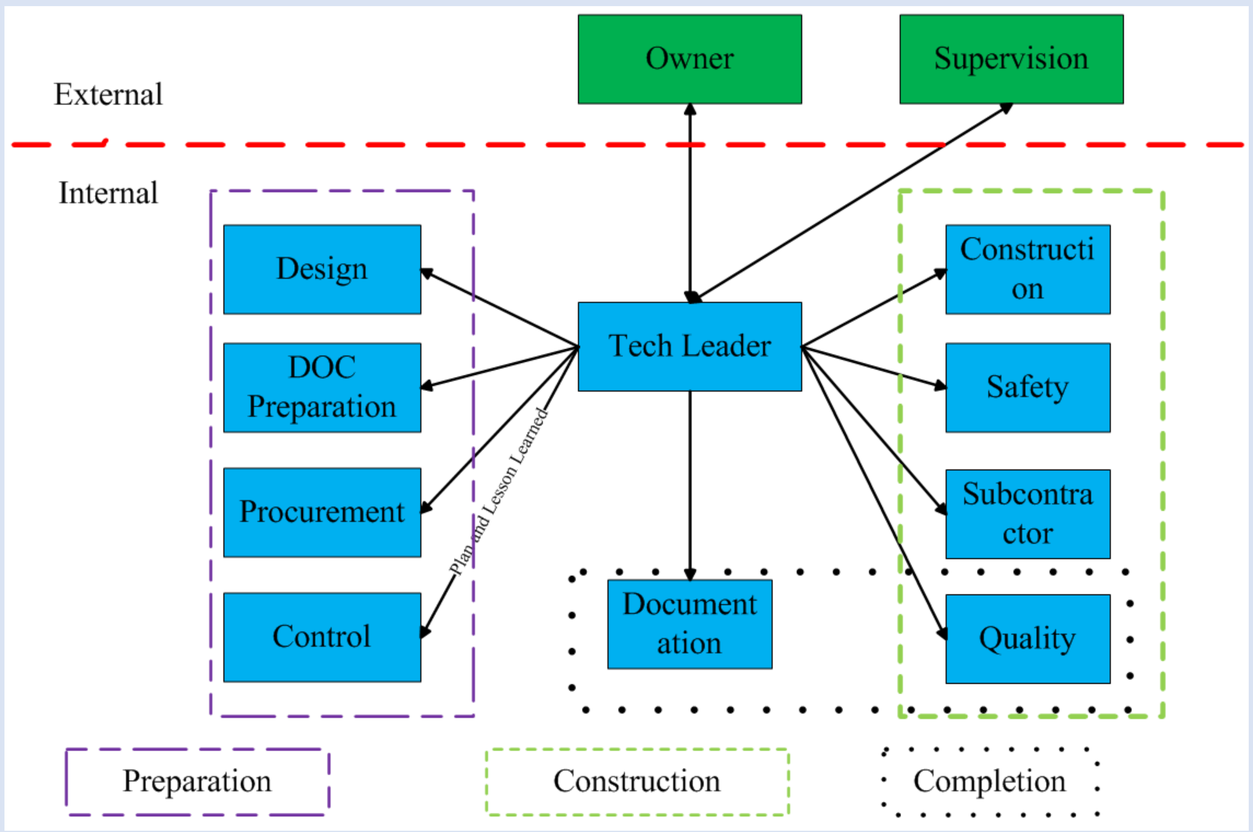
The engineering connotations of different development stages of fusion reactors

Dimension of Engineering	Experimental Facility	Experimental Reactor	Demonstration Reactor	Commercial Reactor
Organizational Model	Led by Research Institutes	Led by Research Institutes with Enterprise Participation	Led by Enterprises with Research Institute Participation	Led by Commercial Operation Companies
Safety Regulatory Systems	Establish Basic Safety Standards	Introduce a Hierarchical Regulatory Framework	Establish a Regulatory and Legal System for Fusion Reactors	Optimize and Iterate the Fusion Reactor Regulatory System
Design and Engineering	——	Full-System Integrated Design	Economic Optimization Design	Factory Standardized Design
Project Implementation	——	Model-Based Systems Engineering (MBSE)	Full-Lifecycle Project Management	Mature Fusion Reactor Project Management System
Industrial Supply Chain	——	Industrial Chain Cultivation	Industrial Chain Cultivation with Diversified Applications	Enhancement of Full-Industrial-Chain Independence
Standardization Framework	——	——	——	Systematization and Independence of Standards

CHALLENGES / METHODS / IMPLEMENTATION

1. Fusion reactor engineering organizations face the dilemma of a disconnect between research institute and enterprise delivery, coupled with talent and engineer mismatch.
2. Nuclear safety regulatory principles urgently need to be clarified.
3. Engineering design capabilities for fusion reactors need to be enhanced.
4. The understanding of fusion reactor project management and its difficulty needs to be deepened.
5. There is a contradiction between the development of the fusion reactor supply chain industry and its actual demands.
6. Existing standard system is incompatible with fusion reactor engineering.

ITER Project Assembly Management with Technology at its Core



OUTCOME

1. Leverage Organizational Advantages to Promote Fusion Energy Development
- Implement proactive policy guidance.
- Utilize enterprises' strengths in innovation and industrial transformation.

2. Formulate Nuclear Fusion Regulatory Policies Balancing Safety and Development
- Clarify the principles of fusion nuclear safety regulation.
- Expand the scope of nuclear material application and research.
- Adhere to the bottom line of nuclear safety culture.

3. Public-Private Cooperation to Cultivate the Fusion Industry Chain
- Give play to the development guiding role of management departments.
- Attach importance to the promotion role of industrial alliances.
- Highlight the facilitation role of iterative industrial incubation.

4. Establish a Nuclear Fusion Standard Framework based on the Top-Level Design
- Implement top-level planning for standards.
- Promote the institutionalized operation of standard formulation.

CONCLUSION

- Research and Establishment of Design Management System for Fusion Reactor Engineering. This system is built and improved based on the existing systems and platforms of the nuclear industry.
- Fusion Reactor Engineering and Construction System led by professional enterprises.
  - Project organization system centered on plant EPC;
  - Project management system with technical management as core;
  - Project control system centered on agile management;
  -Construction management system supported by IT and Digitalization.

ACKNOWLEDGEMENTS / REFERENCES

- Research on the Development of Engineering Applications of Fusion Reactors in China [J]. Strategic Study of Chinese Academy of Engineering