The 1st China-ASEAN Dam Science Popularization Contest

清華大學
Tsinghua University

Research on Intelligent Construction Technology of Dams

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STATE KEY LABORATORY OF HYDROSCIENCE AND ENGINEERING

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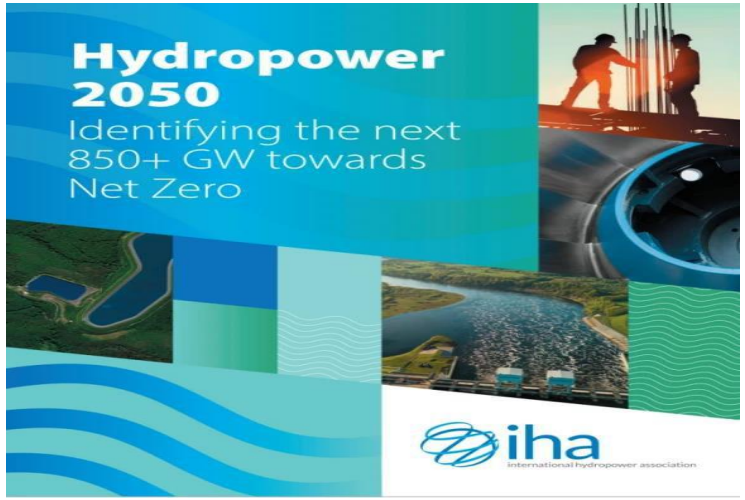
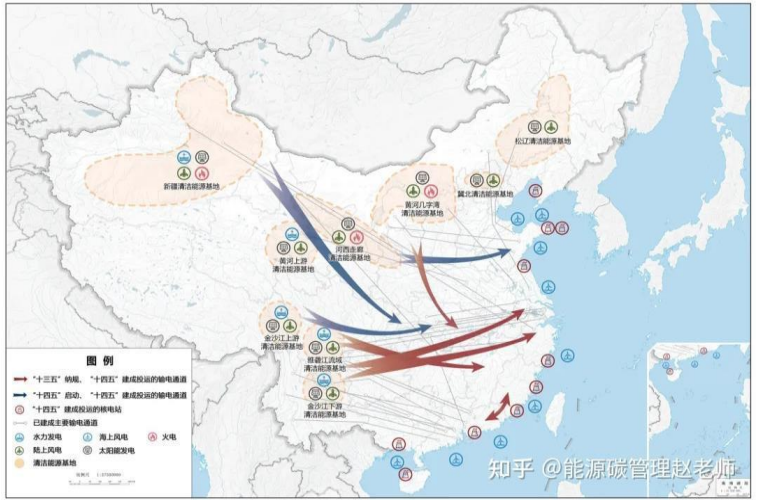
1. Background of Dam Intelligent Construction

Hydropower is a high-quality clean energy with broad prospects for development.

(1) Hydropower 2050, 14th Five-Year Plan, emission peak and carbon neutrality goals. In the next 30 years, China and the world's dam construction will enter a new stage.





World installed capacity will increase by 850 GW.
China's installed capacity will increase by 120 GW.

nine major clean energy bases will add 70 GW of installed capacity. Southwesst, Yellow Riiver etc. (China Energy News)

19.68 million tons of coal will be saved. 51.6 million tons of CO_2 emissions will be reduced. (BHT/Year)

Hydropower 2050（IEA/IRENA） 14th Five-Year Plan “3060”goals

Dam construction follows the trend of the industrial revolution.

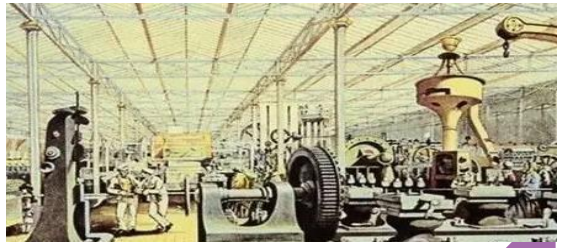
(2) **Safety, high quality, high efficiency, greenness and economy are the goals of dam construction. Intelligent construction of dams is an inevitable trend in the future.**

Steam age

Industry 1.0

(1760-1840)

Machines powered by water and steam are applied to factories.



Electrical age

Industry 2.0

(1840-1950)

Powered by electricity, the factory realizes mass production.

Information age

Industry 3.0

(1950-2020?)

Information technology is used to realize production automation.

Intelligent age

Industry 4.0

(2020-?)

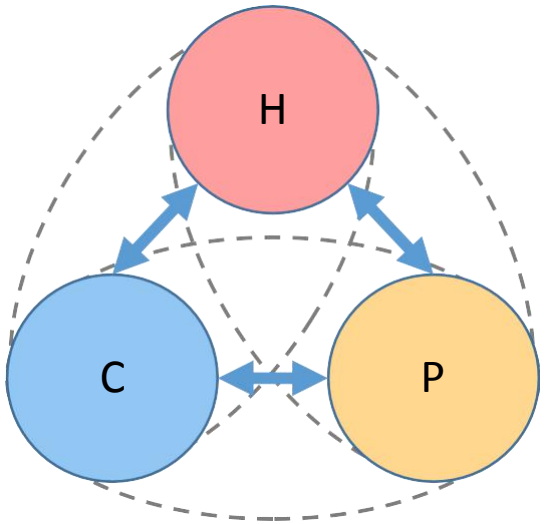
Human-cyber-physical system integration

The new generation of information technology provides new intelligent concepts, technologies, methods and equipments.

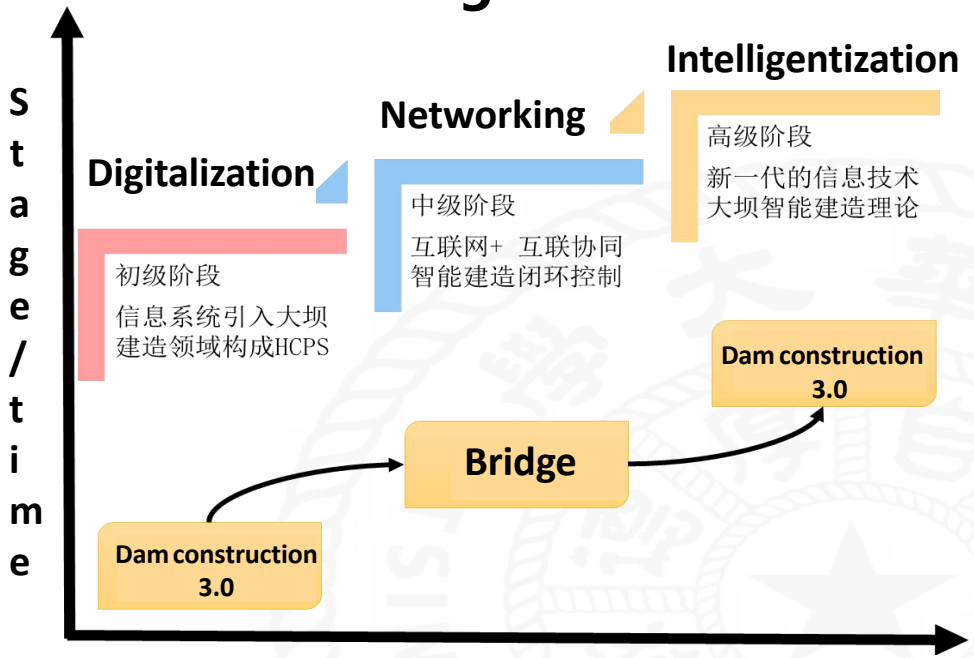
Development stage of dam intelligent construction.

(3) **Digitization** is the **foundation** of intelligent construction, and **networking** as a **bridge** promotes the advancement of digitization to **intelligentization**.

Human-Cyber-Physical-system (HCPS)



Three typical stages of dam intelligent construction.



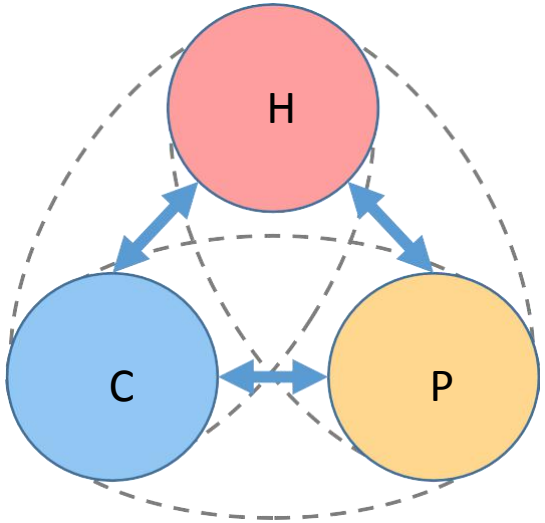
Interconnection, coordination and control.

Life cycle assessment and regulation.

2. Development and Evolution of Dam Intelligent Construction

Digital stage opened the first stage of dam intelligent construction.

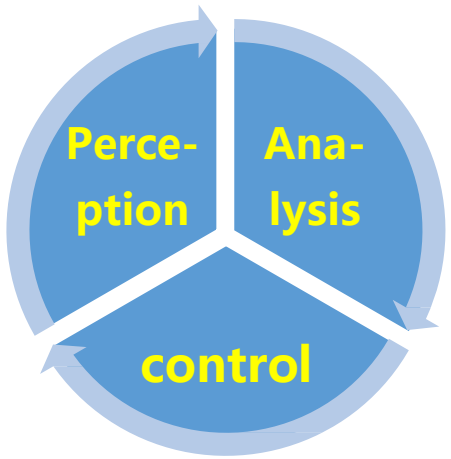
(1) The cyber system was introduced into dam construction, forming an intelligent construction framework with ' human-cyber-physical system ' as the core.

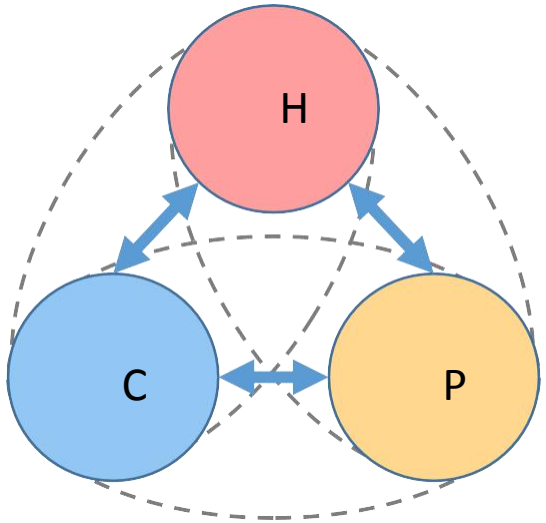


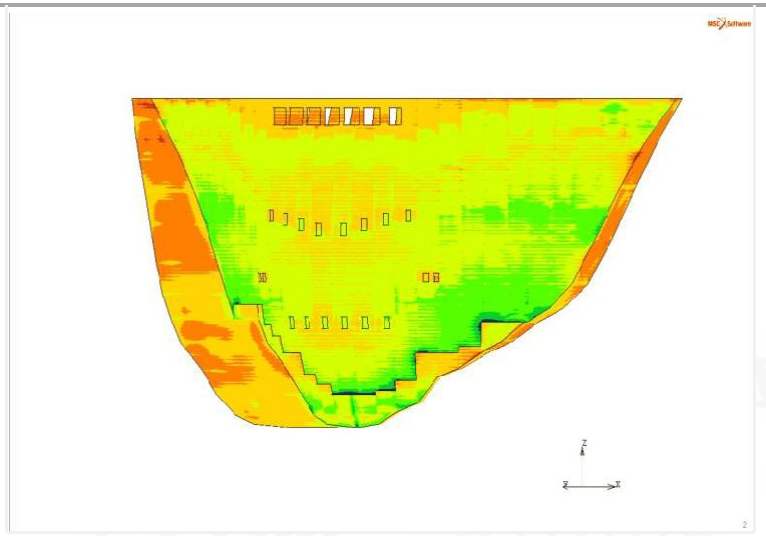
Technical characteristics	System characteristics	Engineering characteristics
Computing, communication, and control technologies are widely used in monitoring, simulation, and management.	Professional knowledge is transferred in the form of mathematical and physical models in HCPS.	The key process of construction is monitored, analyzed, controlled, and managed.

Digital networking stage realized the double closed-loop control of HCPS.

(2) The closed-loop control theory based on "perception-analysis-control" was introduced into HCPS. Each element realized closed-loop control, as well as among them.



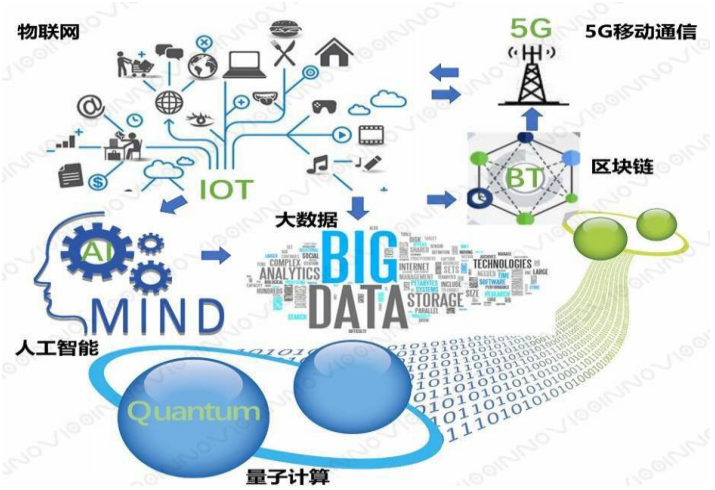


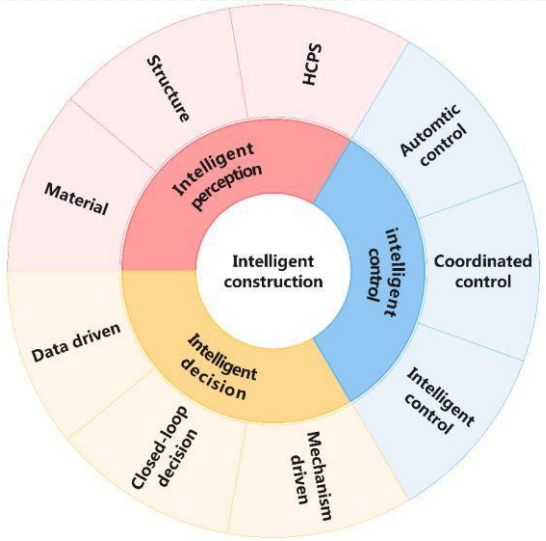


Technical characteristics	System characteristics	Engineering characteristics
Internet technology "Internet +" concept Closed-loop control	Interconnection Integrated management Coordinated control	Whole process, multiple elements Accurate, efficient and precise Dynamic coordination control

Intelligent stage realized the construction based on the drive of data and mechanism.

(3) Cyber and physical systems acquire learning, reasoning, and cognition capabilities. HCPS become smarter and more efficient, providing a way to solve complex problems.





New gen-information technology

Intelligent decision +auto- control =Intelligent control

Learning, reasoning, cognition

Intelligent perception,analysis, control, management

Multi-objective optimization

Safe, high quality, efficient, economical and green

Technical characteristics | System characteristics | Engineering characteristics

3. Research Progress of Dam Intelligent Construction

New Perspective on Intelligent Construction

(1) **Perspective change: In order to realize intelligent construction, solve complex problems through mechanism and data-driven methods, including Newton, big data and Merton's law.**

Newton's Law

- mathematical model
- Complex calculation
- Mechanism driven
- causation

Correlativity

- No causation
- Non-explicit
- Data driven
- Correlation

Merton's Law

- Complex system
- Uncertainty
- Uncontrollable
- Guide direction

Mechanism and data-driven methods provide a way to solve highly complex, highly nonlinear, time-varying, and uncertain problems.

(2) **Theory development: Intelligent control is the core of intelligent construction. Intelligent control theory provides a paradigm for structural safety assessment and performance control.**

Definition

Design a dam construction controller.

The controller has the functions of information perception, analysis abstraction, cognitive learning, decision-making reasoning, and feedback control.

It can make adaptive adjustments in the dynamic changes of the information of various elements in the construction process.

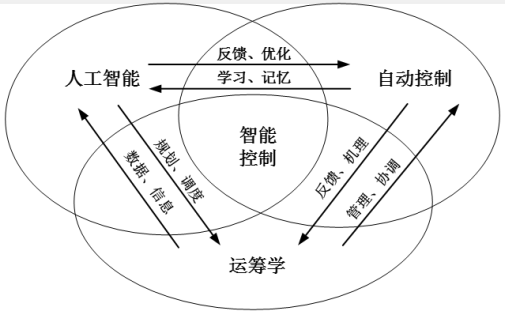
Basic characteristics

Uncertain model solution

Multi-objective optimization

Multidisciplinary cooperation

Theoretical structure



Control target

Intelligent organization and decision-making. Autonomously drive the controlled object to achieve the control target.

Control System

Multi-dimensional info-perception

Multi-objective decision-making

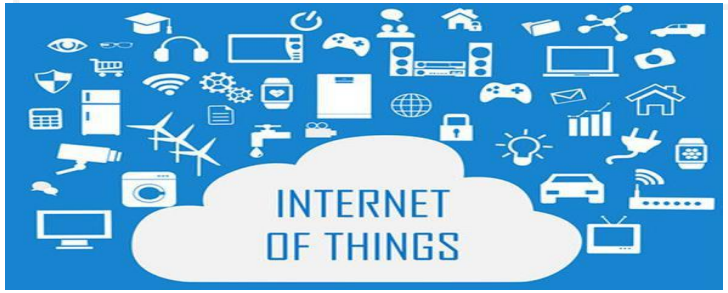
Multi-element automatic control

Life cycle safety performance evaluation, structural service status control, construction risk prediction and early warning, cost control, etc.

New Technologies for Intelligent Construction

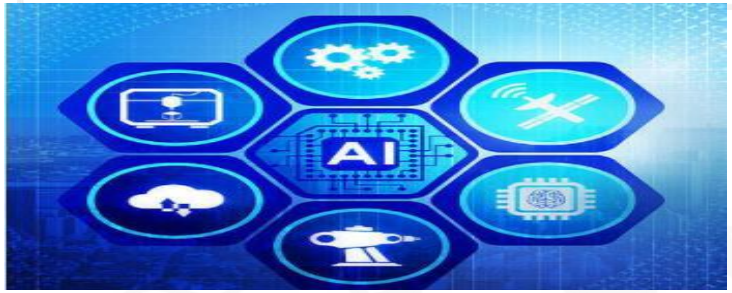
(3) Technology upgrade: New generation of technology including AI, IOT, big data, cloud computing, etc. is the core driving force for the promotion of intelligent construction.

Internet of Things

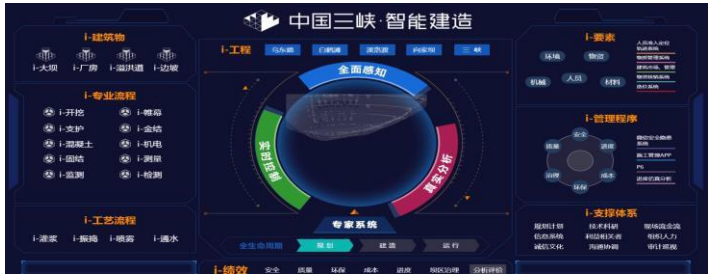


Big data and cloud computing

Artificial intelligence

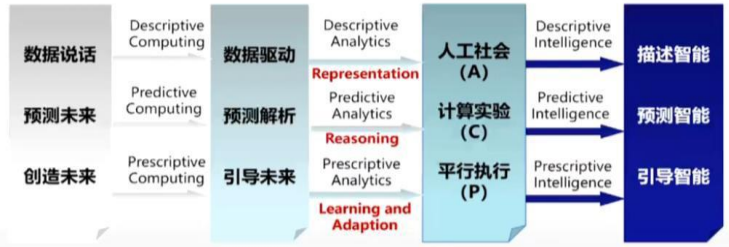


DIM/BIM



Digital twin

ACP



Multi-level software and hardware support, powerful data calculation and analysis capabilities, and diverse intelligent control management technologies

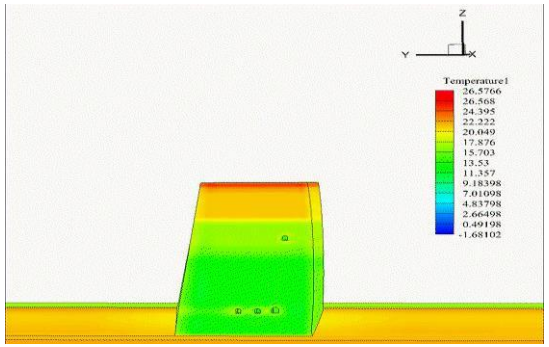
New Platform for Intelligent Construction

(4) Platforms based on professional knowledge provide theoretical foundation, data and technical support for the analysis and control of the dam construction process.

Material performance testing

- Multiscale
- performance
- mechanism
- Modeling

Structural simulation analysis

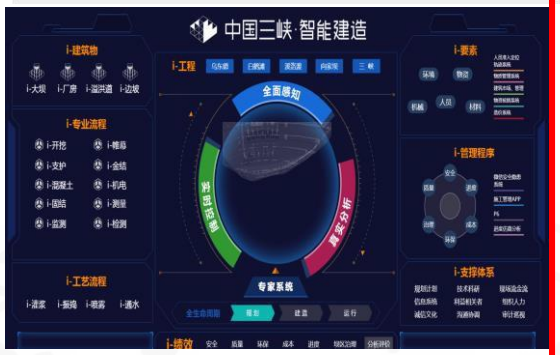


- Load combination
- Complex boundary
- Dynamic Process
- Multi-field coupling

Intelligent monitoring technology

- Monitoring theory
- Sensing equipment
- equipment control
- Spatio-temporal monitoring

Information Management System



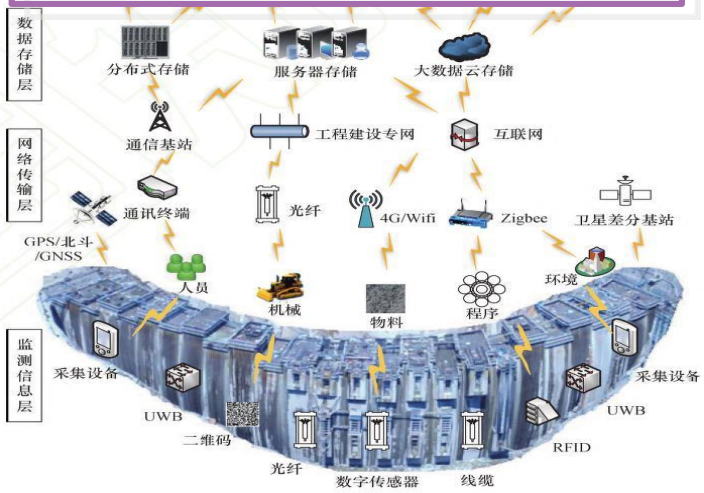
- People, equipment
- Material resources
- Process flow
- Process control

Analysis of performance, inspection plans, tracking process, and evaluation status provide technical support for real-time tracking and analysis of the entire process of dam intelligent construction.

Application Cases of Intelligent Construction

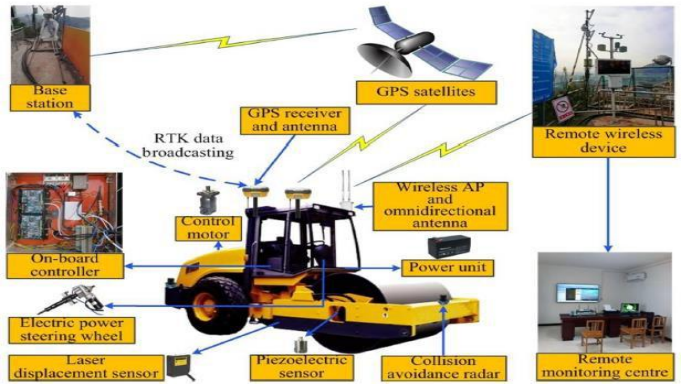
(4) Intelligent construction theory is widely used in construction. Including **intelligent perception analysis**, **decision-making and control**, **execution and management**.

Perception and analysis



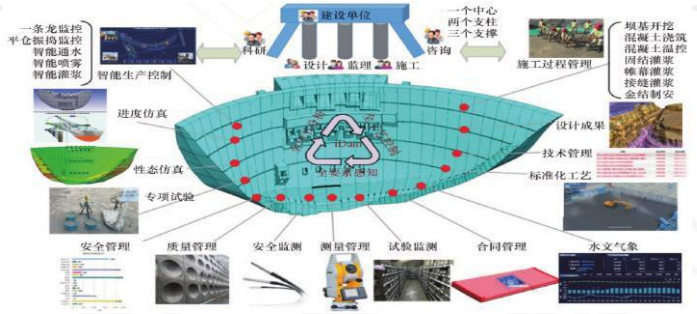
- Parameter inversion system
- Intelligent monitoring system
- Identification & warning system

Decision and control



- Unmanned compaction, crack prevention
- Schedule optimization, traffic dispatch
- Quality control, cost control

Management and execution

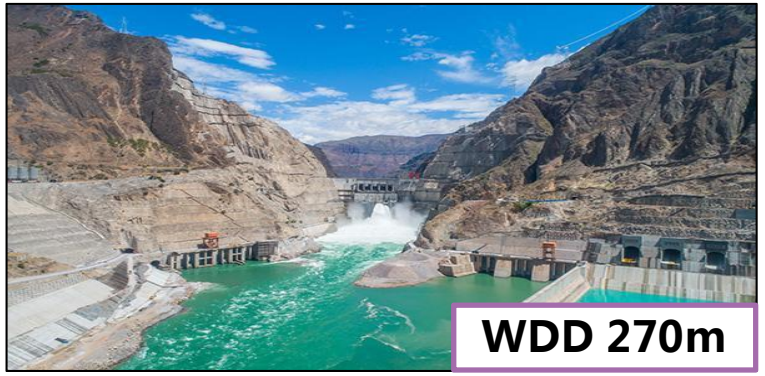


- Industry-University-Research Management System
- Spray, grouting
- Vibration, curing
- Simulation, detection

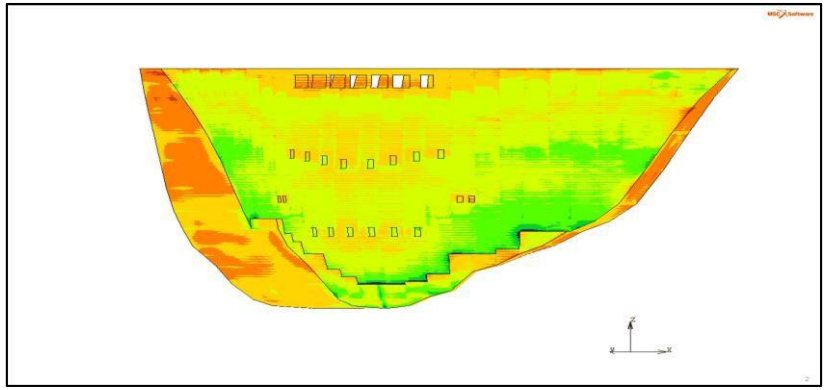
Intelligent technology promotes the transformation of ideas, theoretical innovation, method progress and technological breakthroughs.

(5) 300m-level super high arch dam. The whole process structure simulation, multi-scale simulation, multi-element intelligent monitoring and control are realized.

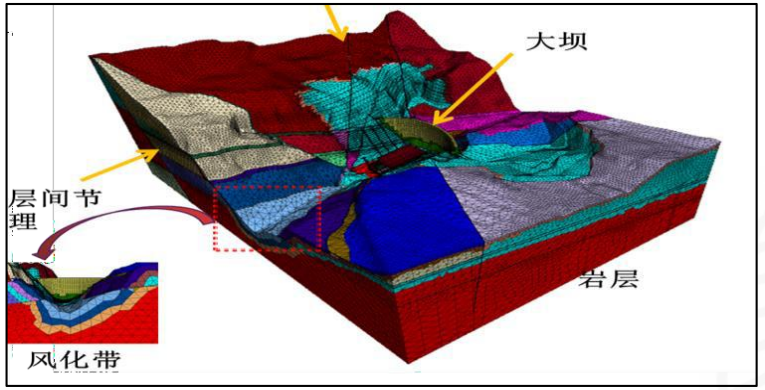

XLD 285.5m


WDD 270m

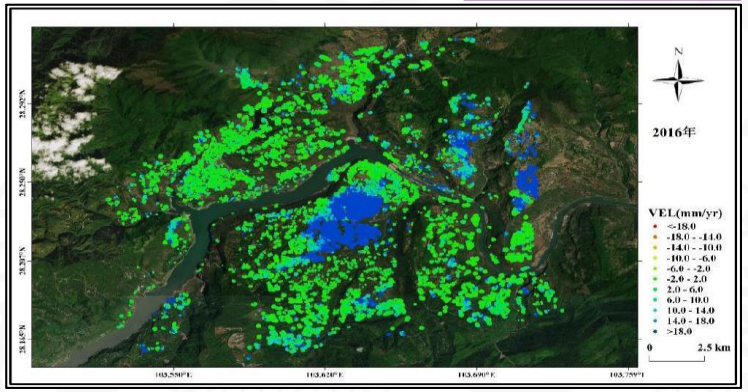

BHT 289m



Simulation of the whole process



Sophisticated simulation



Multi-scale monitoring and control

Smart dam was built. The goal of building a seamless dam has been achieved.

4. Future trend of Dam Intelligent Construction

Three Levels of Intelligence

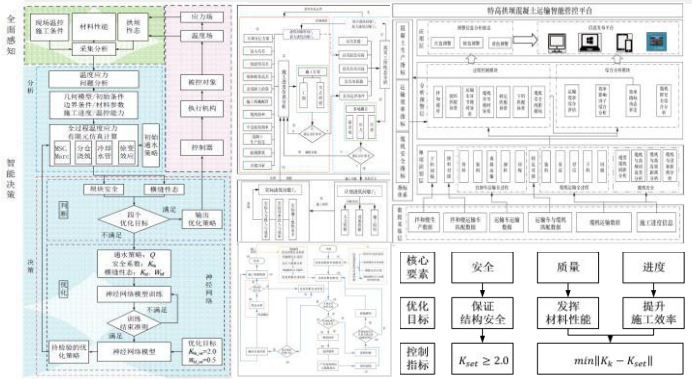
(1) The theory are mainly focused on execution-level intelligence, and there is still a lot of room for development of coordination-level and organizational-level intelligence.

execution-level

Unit intelligence

- Aiming at the specific problems of construction management, build intelligent unit control. (Such as: PID, GA, CNN, BP, etc.)

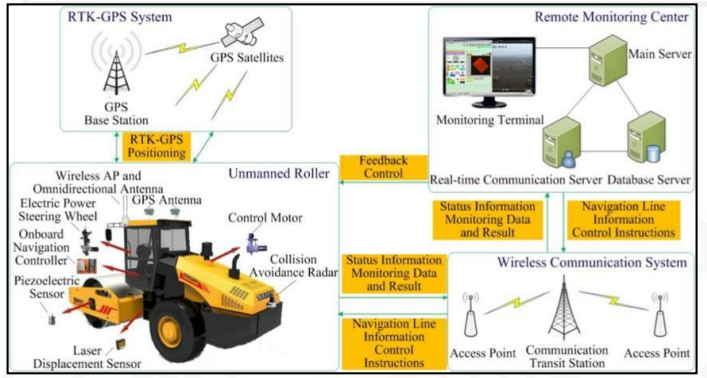
coordination-level



Multi-agent intelligence

- Committed to multi-element, multi-objective, multi-object optimization and regulation, (Such as: crack control, rolling, dispatching, etc.)

organizational-level



Whole process intelligence

- Committed to multi-agent competition game and joint collaborative control, forming the optimal multi-element collaborative construction plan for the whole process of dam construction.

Coordinate three levels to achieve top-level intelligent design and construction.

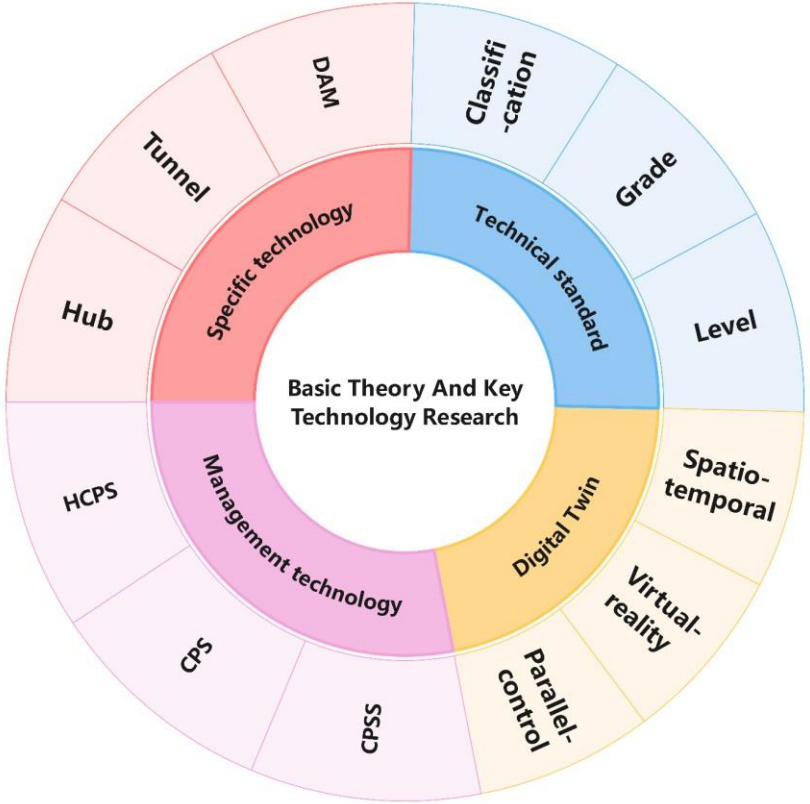
(2) **Basic research includes basic theories, and information collaboration platforms. Key technologies include construction, management, standards and other aspects.**

Specific technology

① Concrete dam
② Earth-rock dam
③ Power station structure
④ Tunnel structure
⑤ Hub Engineering

Management technology

① HPS （ Accurate ）
② CPS （ Unmanned）
③ HCPS（ Coordinated ）
④ CPSS（ diversification ）



Technical standard

① Engineering category
② Engineering grade
③ Intelligent level
④ System classification
⑤ The whole process

Digital Twin

① Digital twin
② Multi-source heterogeneous
③ Distributed processing
④ Spatio-temporal interaction
⑤ Virtual and real synergy

To achieve the goals of safety, high quality, efficiency, greenness, and economy during the construction of the dam.

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Thanks for your watching.