中国智能高速铁路的发展与展望

Development and Exploration of China's Intelligent HSR

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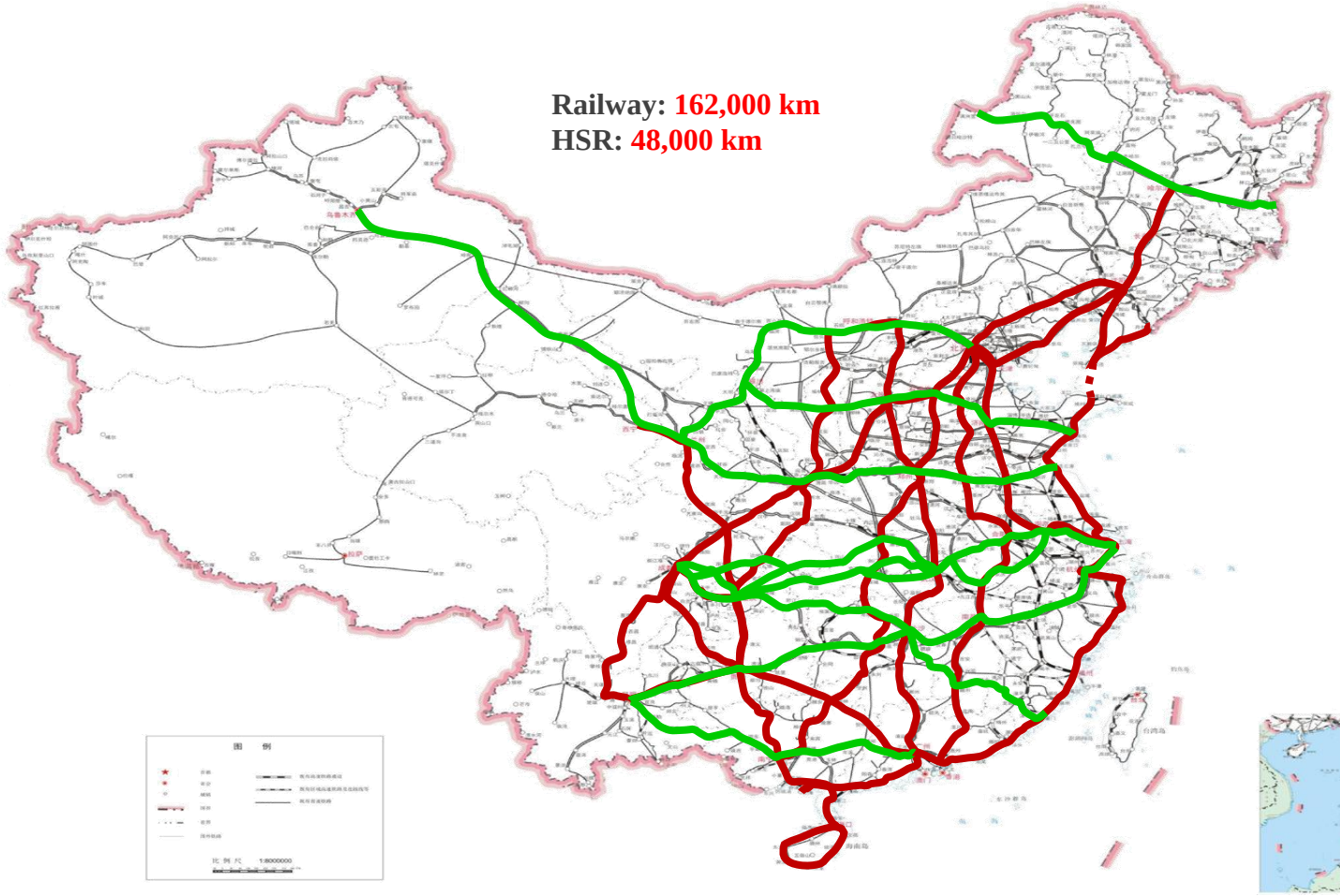
1.1 中国高速铁路发展 Development of HSRs in China

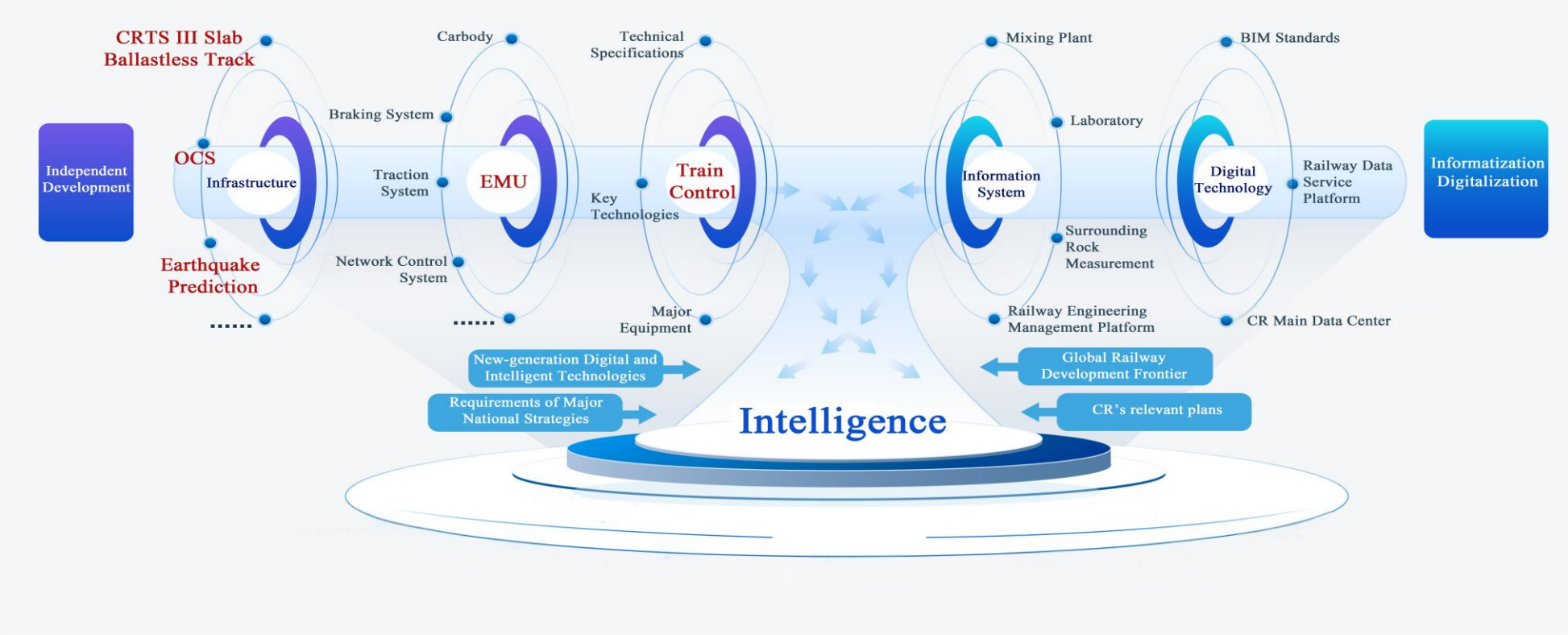
Building on the completed four north-south and four east-west HSR corridors, the denser eight north-south and eight east-west corridors are taking shape in China. These advancements highlight China's globally advanced overall technical capabilities and world-leading technical capabilities in certain fields.



- **Longest** operating length
- **Largest** scale of construction in progress
- **Highest** commercial operating speed
- **Most complete** coverage of technologies
- **Most diverse** operating scenarios

1.1 中国高速铁路自主化 Independent Development of HSRs in China

Since 2012, CR has achieved fully independent development of core railway equipment, including infrastructure, train control, and rolling stock. Additionally, it has successfully built its first overseas HSR - Jakarta-Bandung HSR - in Indonesia.



1.2 国家重大战略需求Requirements of Major National Strategies

Outline on Building China's Strength in Transportation
2019.9

Outline of the National Comprehensive Three-dimensional Transportation Network Planning
2021.1

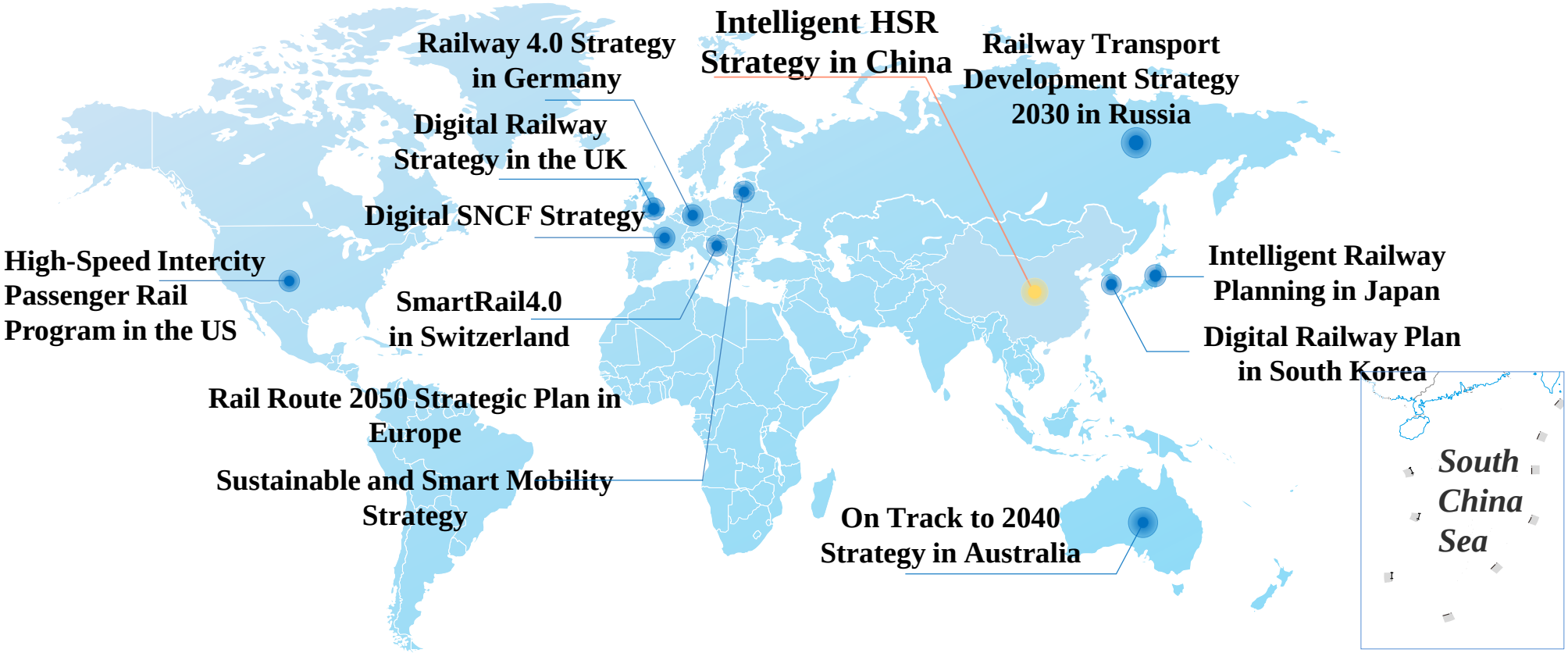
Outline of the 14th Five-Year Plan and Long-Range Objectives Through the Year 2035 for National Economic and Social Development of the People's Republic of China
2021.3

Plan for the Overall Layout of Building a Digital China
2023.2



1.3 世界铁路发展前沿 Global Railway Development Frontier

Countries with a developed railway industry, including Germany, France, Switzerland, the UK, and Japan, have successively introduced plannings and strategies for the development of intelligent railways, demonstrating that digitalization and intelligence are emerging as key trends in the global development of railways.

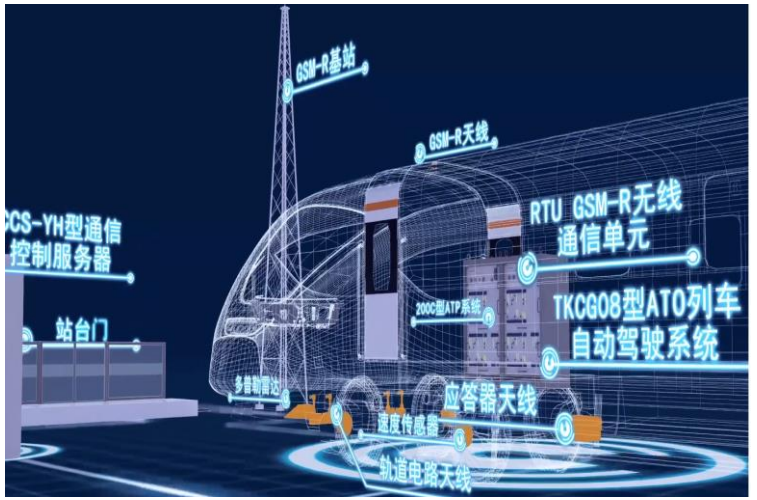


1.4 中国高铁持续领跑需要
Requirements for Sustaining China's Leadership in HSRs

To maintain China's leadership in HSR technology in the world, support the high-quality development of HSRs in China, and fulfill strategic goals such as building China's strength in transport, it is imperative to develop intelligent HSRs that integrate new technologies, particularly those related to digitalization and intelligence.



Sustained Leadership and High-quality Development in HSR Field



Full Life Cycle Coordination Across Entire Industry Chain



Improvements in Service, Safety and Efficiency

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2.1 智能高铁的科研项目支撑
Scientific Research Projects Supporting Development of Intelligent HSRs

Since 2017, systematic efforts have been made in **scientific and technological innovation in the development of intelligent HSRs**, supported by various scientific research projects.

National Key R&D Program

Key Technologies and Demonstration on Intelligent Services of Beijing-Zhangjiakou HSR

Major Consulting Project of China Academy of Engineering

Research on Intelligent HSR Strategy (2035)

International Union of Railways (UIC)

Related UIC Research Projects

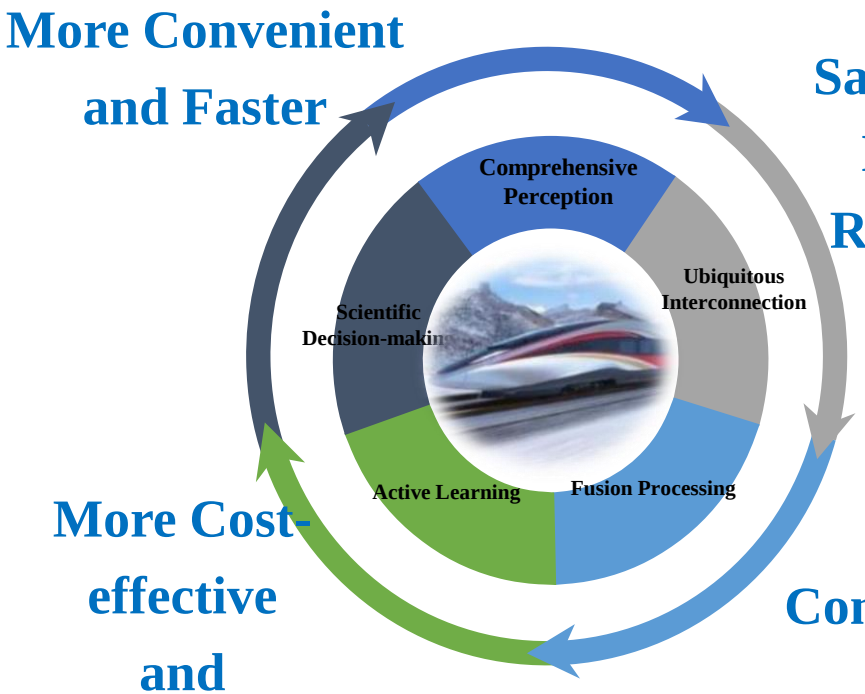
CR

Series of Research Projects on Intelligent Railway



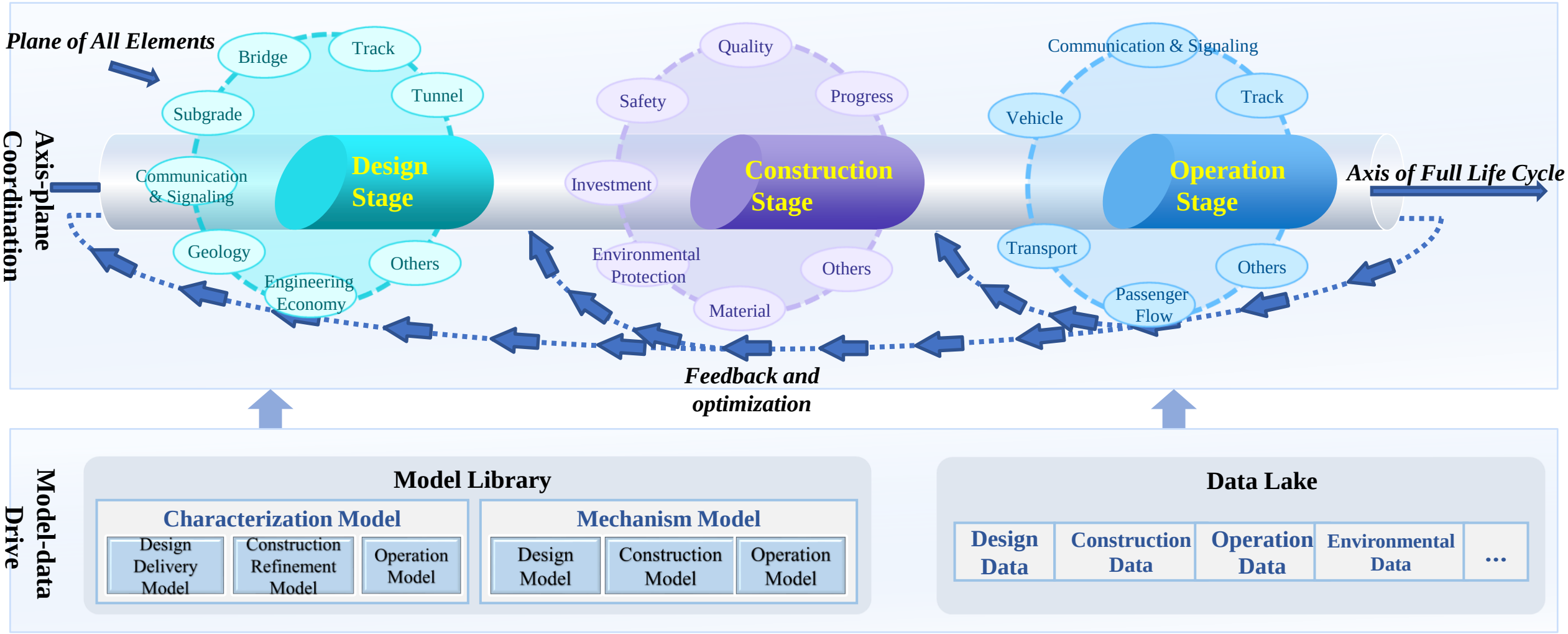
What is intelligent HSR, and what does it mean?

- **One main line:** integrated management throughout the full life cycle of HSR design, construction and operation.
- **Five characteristics:** comprehensive perception, ubiquitous interconnection, fusion processing, active learning and scientific decision-making
- **Five goals:** achieve improvements in five areas and optimal overall efficiency.



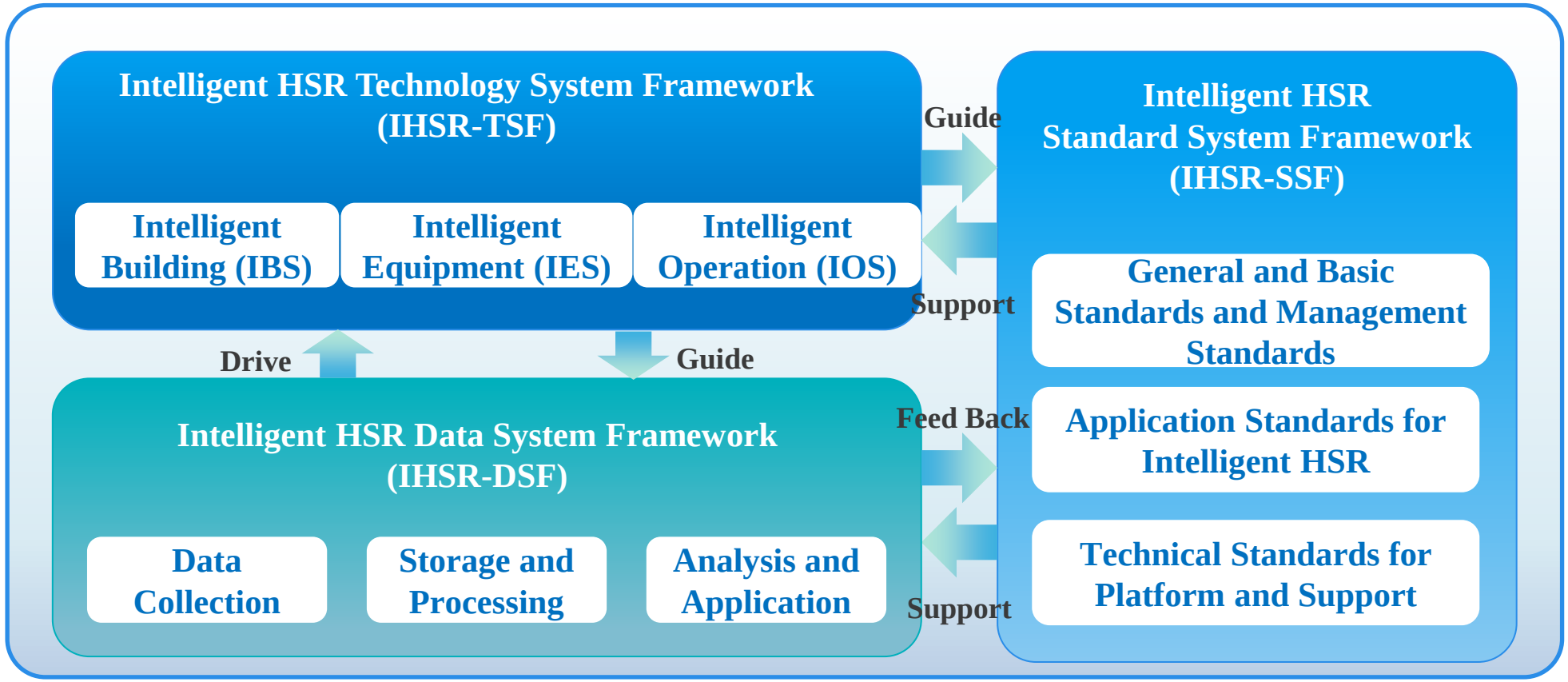
2.3 理论创新—“模数驱动、轴面协同”理论
Theoretical Innovation - “Model-data Drive, Axis-plane Coordination” Theory

Driven by abundant models and massive data, this approach aims to optimize the overall efficiency of giant systems, supporting coordination throughout the full life cycle and across all elements.



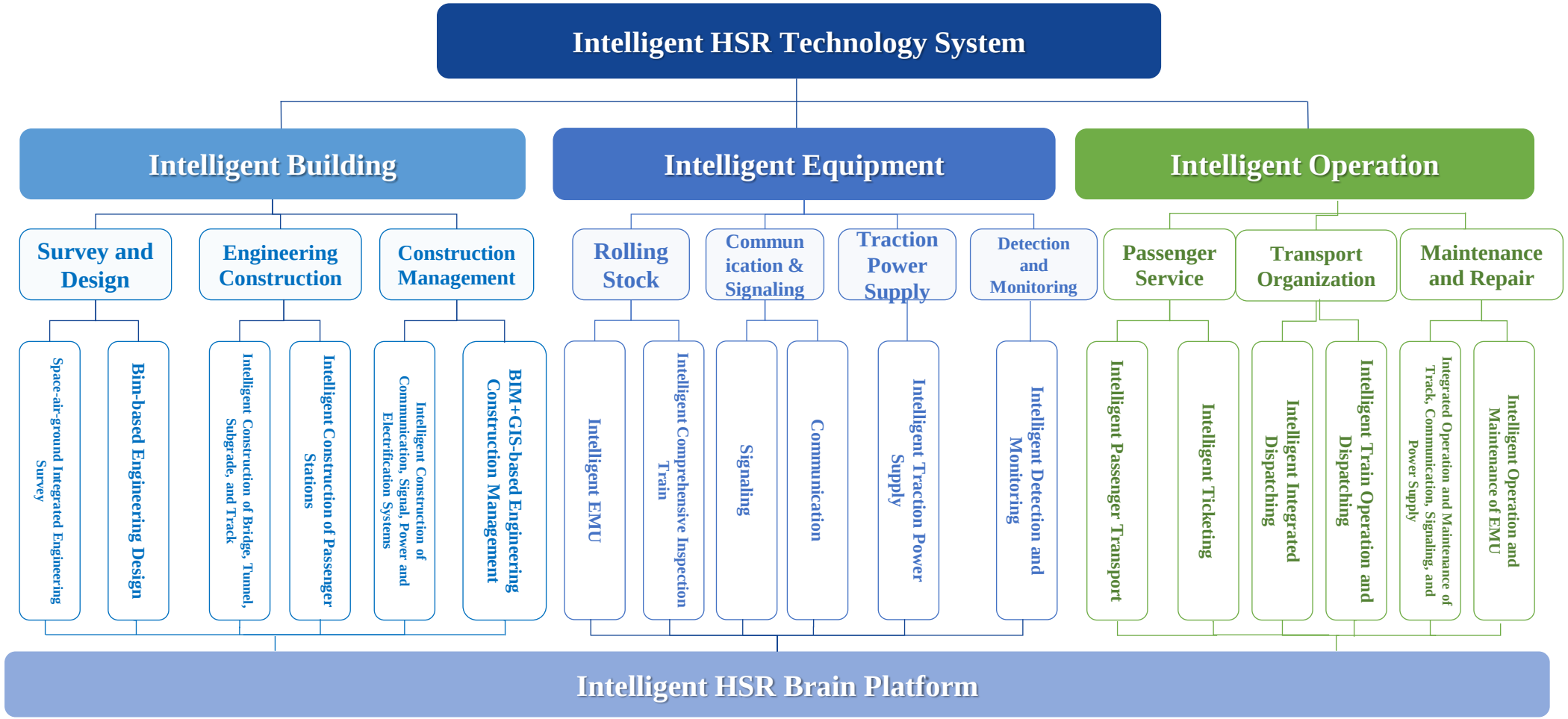
2.4 体系创新System Innovation

An intelligent HSR system architecture has been established, featuring the integration of technology, data, and standards to provide comprehensive coverage of intelligent building, intelligent equipment, and intelligent operation.



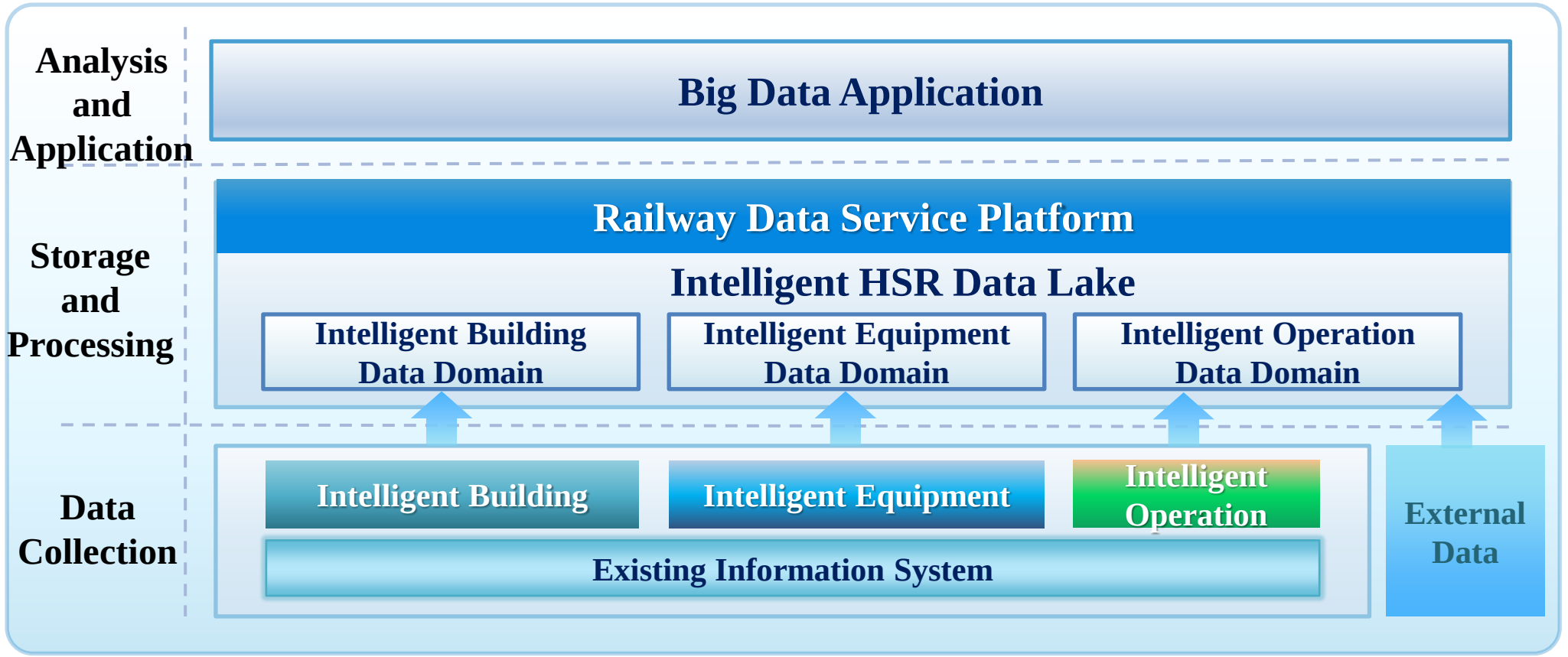
2.4 智能高铁体系架构—技术体系
Intelligent HSR System Architecture - Technology System

The "1-3-10-18+N" Intelligent HSR Technology System Framework has been initially proposed, leveraging an innovated design approach that incorporates hierarchy, grading, and classification to combine both stable and sensitive states.



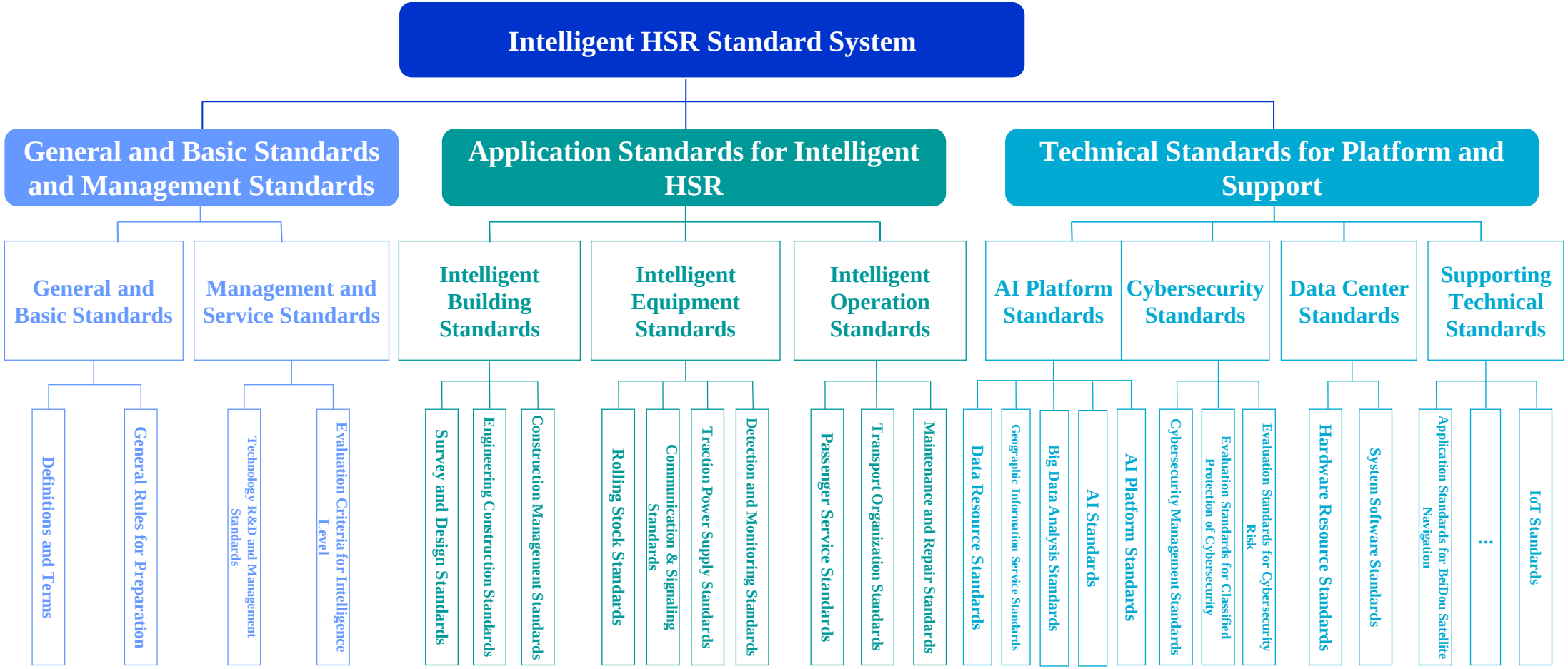
2.4 智能高铁体系架构—数据体系
Intelligent HSR System Architecture - Data System

Based on a storage structure for data models covering various subjects, such as engineering construction, rolling stock, infrastructure, and operation services, an innovative intelligent HSR data system framework has been established. This framework focuses on the full life cycle and integrates a data gathering layer, a storage and processing layer, and an analysis and application layer.



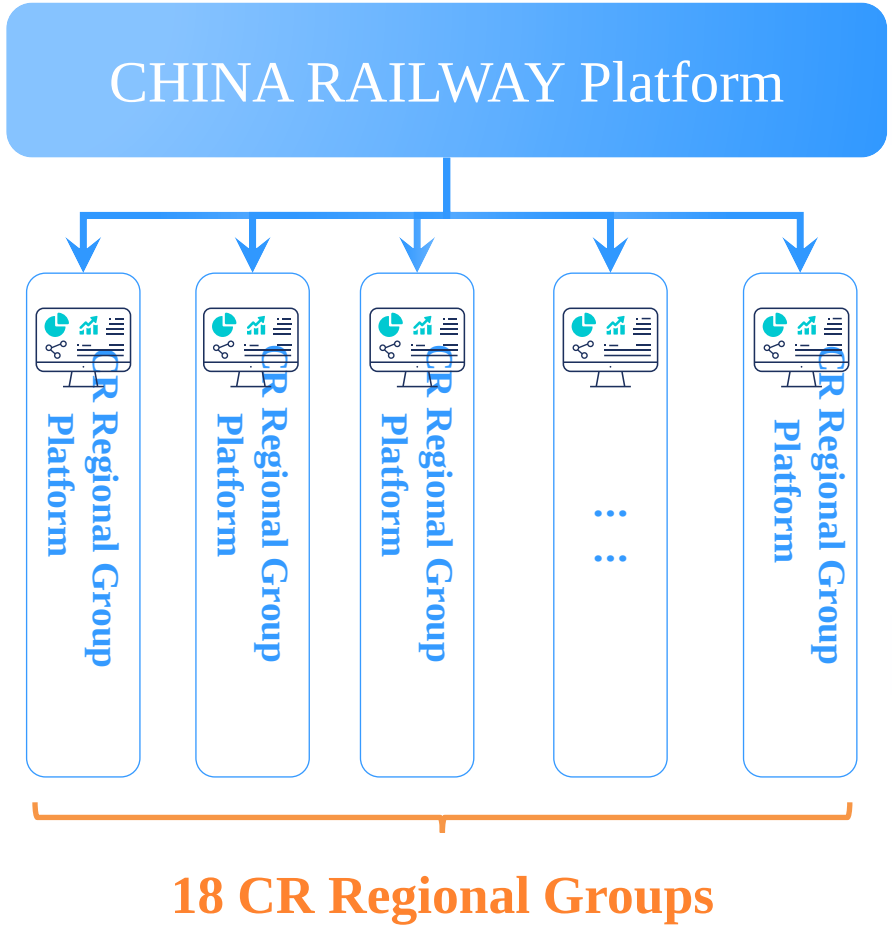
2.4 智能高铁体系架构—标准体系
Intelligent HSR System Architecture - Standard System

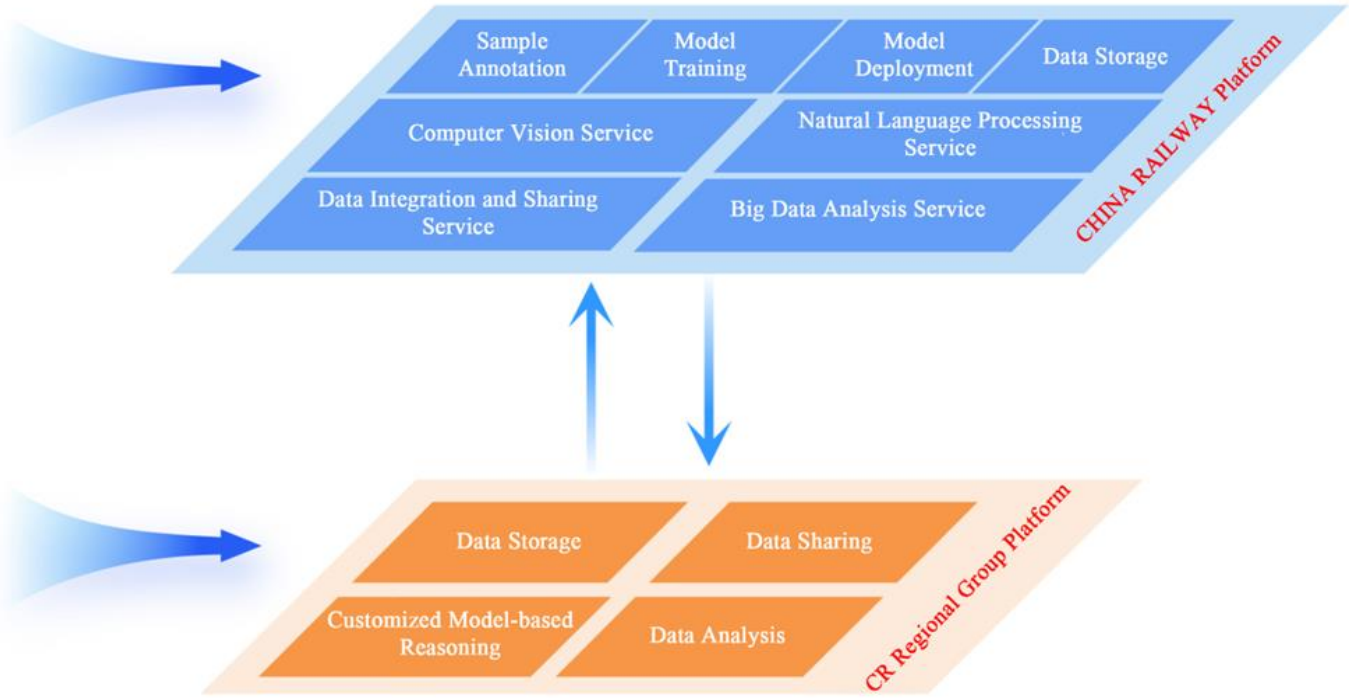
An innovative multi-level, iterable and extensible intelligent HSR standard system framework has been established, utilizing a mapping model of standard categories based on clustering reconstruction and object integration.



2.5 平台创新 Platform Innovation

A **railway big data and AI platform** has been developed and **deployed at two levels: CHINA RAILWAY and the CR regional groups**. This platform supports the application of big data and AI technologies across railways nationwide and enables **real-time linkage** of data between the two levels, along with **joint calculations of multiple models.**

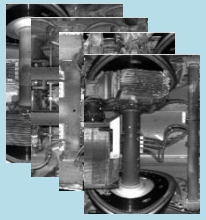




2.5平台创新—计算机视觉大模型
Platform Innovation - Large Model of Computer Vision

Sample libraries have been established for scenarios in five professional fields: rolling stock, infrastructure, railway construction, passenger services at stations, and environmental safety. These libraries have been utilized by 18 CR regional groups for applications such as environmental management and control for track safety and OCS foreign object detection, achieving a recognition accuracy rate of over 90% with zero missing reports.

Rolling Stock



Motor | Axle Disc | Bolt | Wheel | Wheel | Axle | Condenser Fan | Brake Caliper | Faults | ……

For TEDS, TFDS, cargo inspection and identification, intelligent train operation-receiving and departure, end-of-train operation inspection, and train number recognition, etc.

Infrastructure



Rail | Fastening | Subgrade | Tunnel | Slope | Turn out | Track Circuit | Feeder Cable | Retaining wall | ……

For perimeter security, railway environmental safety control, OCS (4C) monitoring, e.g. foreign object intrusion detection, intelligent patrol and maintenance planning, etc.

Railway Construction



Excavator | Loader | Rail Car | Rail Welding Machine | Welding Equipment | Stone Stacking | Special Materials | Work Area | Warning Signs

For construction safety monitoring, resource optimization, intelligent scheduling, and collaborative operations, etc.



Environmental Management and Control for Track Safety

Passenger Services at Stations

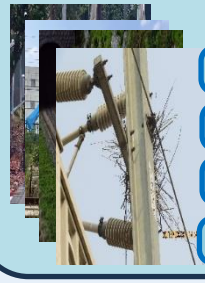


Backpack | Luggage | Baby Stroller | Water Dispenser | Toilet | Power Bank | Controlled Knives | Firefighting Equipment | Station Screen | ……

For scenarios at stations, such as searching for lost passenger items, safety warnings and interventions, personnel flow management, special group care, and public service guidance

Sample Library for Large Model of Computer Vision

Environmental Safety



Landslide Mass | UAV | Bird Nest | Falling Tree | Wild Animal | Geological Fracture | Light Foreign Object | Illegal Intrusion | ……

For track environment monitoring, real-time safety alerting, and environmental impact assessment, etc.



OCS Foreign Object Detection

Data Size
- 2.7 million images

Normal Samples
- 2 million images

Abnormal Samples
- 700 thousand images

Tag Population
- 5 million+

2.5 平台创新—自然语言处理大模型
Platform Innovation - Large Model of Natural Language Processing

A China railway-specific large AI model has been developed, capable of performing various tasks including railway expertise Q&A, knowledge tracing, office task assistance, document writing, code generation and multi-turn dialog.





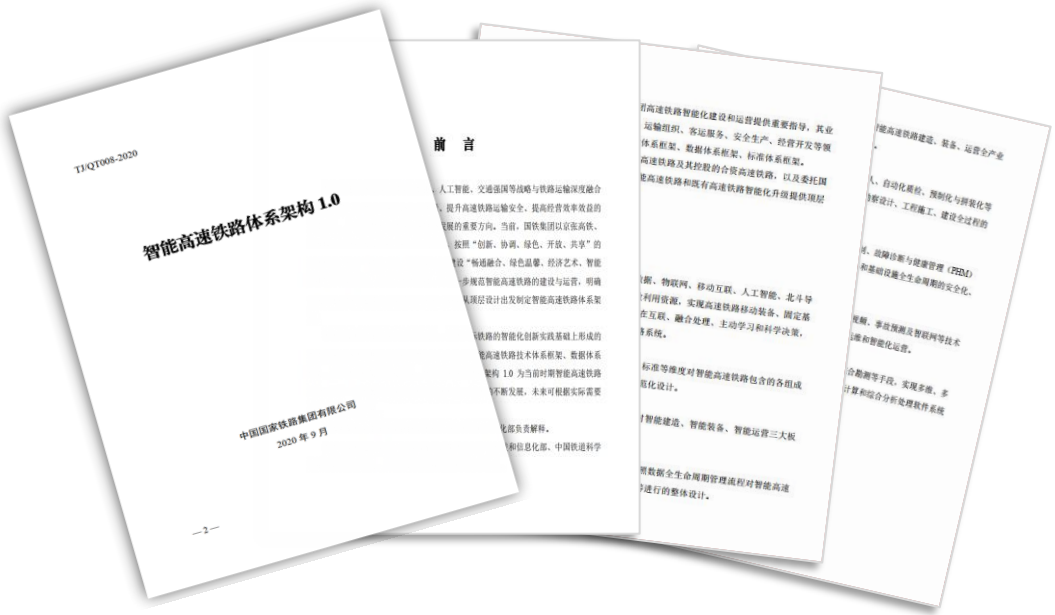
China Railway Large AI Model

2.6 体系成果的应用System Innovation Applications

CHINA RAILWAY has released the *Intelligent HSR System Architecture 1.0* (TJ/QT 008-2020) to provide comprehensive guidance for the construction of intelligent HSRs in China. Moreover, the intelligent HSR technology system has been adopted by the International Union of Railways (UIC), providing China's intelligent HSR solutions to countries around the world.



UIC Technical White Paper



Approved Version of Intelligent HSR System Architecture 1.0

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3.1 京张高铁重大工程Beijing-Zhangjiakou HSR

As a vital transport infrastructure serving the 2022 Beijing Winter Olympics, the Beijing-Zhangjiakou HSR represents the world's first intelligent HSR, a great new project to inherit and develop Zhan Tianyou's spirit of innovation, and a key driver for the integrated and coordinated development of Beijing-Tianjin-Hebei Region.





Cultural Heritage



Transport Guarantee



Economic Growth

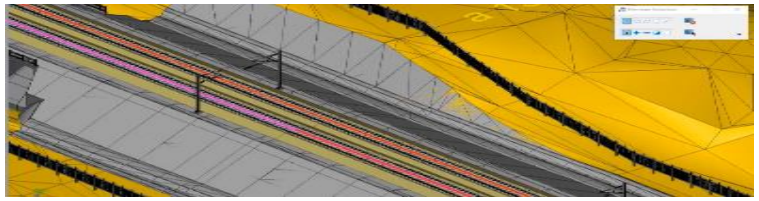


Intelligent Demonstration

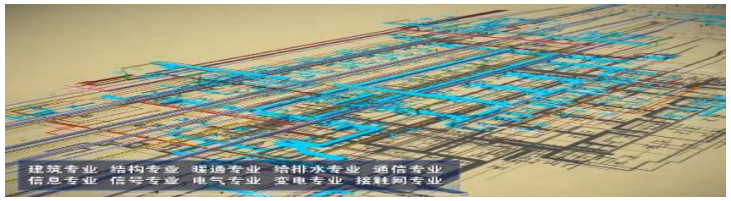
3.2 智能建造技术创新Innovations for Intelligent Building Technologies

We manage to resolve key challenges encountered in full life cycle management, BIM-based collaborative design of technical parameters, as well as the intelligent building of all domains involved (track, bridge, tunnel, rail, communication, signal, power supply, electrification and passenger station). Digital factory, intelligent building, prefabricated construction, refined control, and other innovative progress are achieved.

Collaborative Design



BIM Collaborative Design Platform



Multi-discipline Collaborative Design



Multi-source Data Fusion, etc.

Intelligent Building



Intelligent Factory for Rebar Processing



Intelligent Bi-block Sleeper Yard



Unmanned Slab Yard



Intelligent Bridge Construction



Intelligent Tunnel Construction

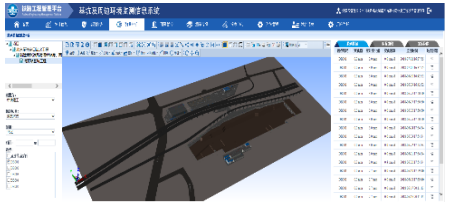


Intelligent Track Construction, etc.

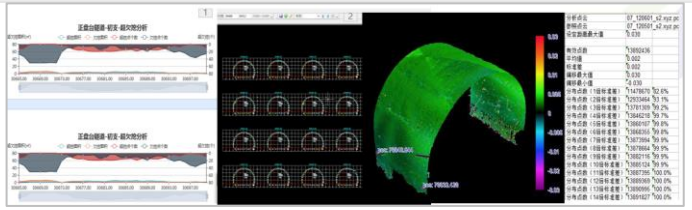
Engineering Management



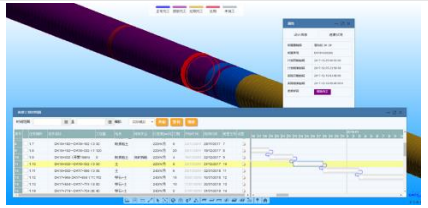
Engineering Management Platform



Safety Management



Quality Management



Progress Management, etc.

3.2 智能建造技术创新Innovations for Intelligent Building Technologies

Underground Badaling Great Wall Railway Station



Qinghuayuan Tunnel



Critical & Complex Projects

Qinghe Railway Station

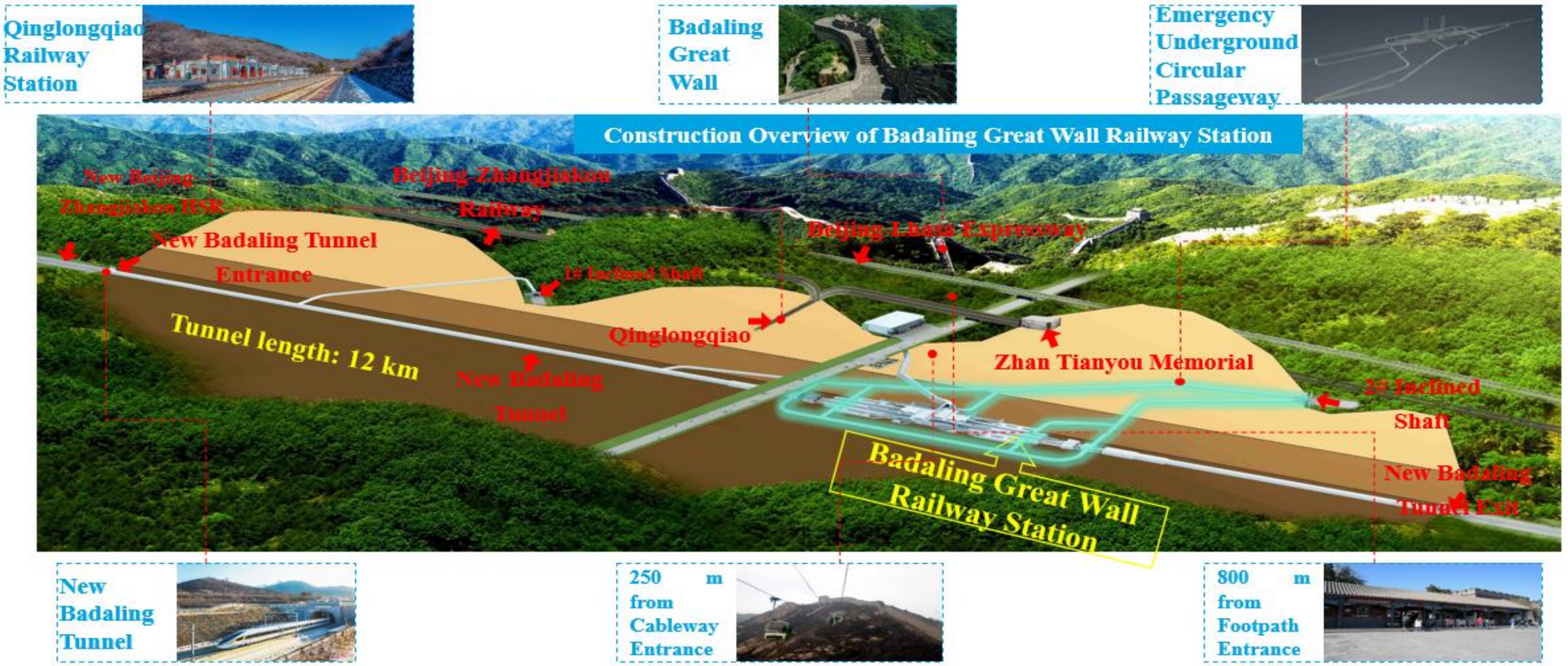


Guanting Reservoir Extra Long Bridge



3.2 智能建造技术创新——八达岭地下长城站 Innovations for Intelligent Building Technologies - Underground Badaling Great Wall Railway Station

Badaling Great Wall Railway Station is a subsurface-excavated HSR station with the world's "**largest construction scale, deepest burial depth, longest excavation span, and the most complex chamber structure**".



3.2 智能装备技术创新Innovations for Intelligent Equipment Technologies

As our R&D efforts deliver the dedicated systems for intelligent EMUs and traction power supply, a world record of 350 km/h ATO operation has been achieved.

Intelligent EMU



"Blissful Dragon and Phoenix"



"Auspicious Snow in Early Spring"



Technical Characteristics, etc.

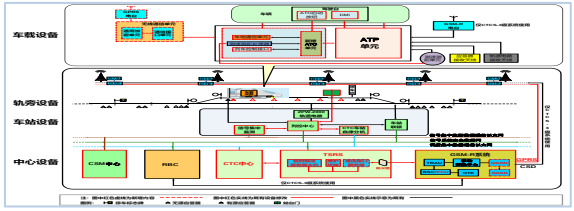
ATO



350 km/h ATO



Automatic & Accurate Train Stop



Functional Architecture, etc.

Intelligent Traction Power Supply



Intelligent Traction Substation



Intelligent Power Supply Equipment



Intelligent Traction Power Supply System, etc.

3.3 智能运营技术创新Innovations for Intelligent Operation Technologies

The complete set of technologies for intelligent operation (intelligent ticketing, passenger station service, and O&M) help realize contactless station access, intelligent passenger service & operation control at the station, intelligent infrastructure O&M, and EMU condition-based maintenance, etc.

Intelligent Ticketing



Electronic Ticketing

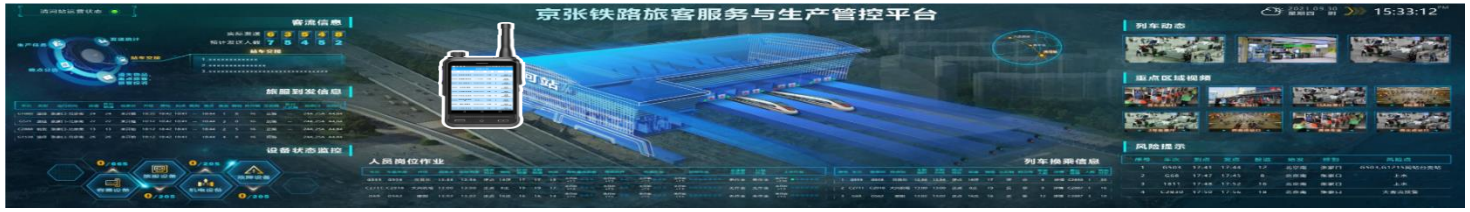


ID-Holder Authentication

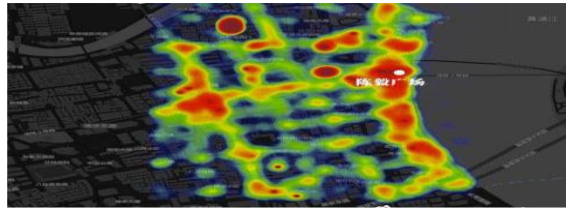


Contactless Station Access, etc.

Intelligent Passenger Station



The “Brain” - Intelligent Passenger Station Platform

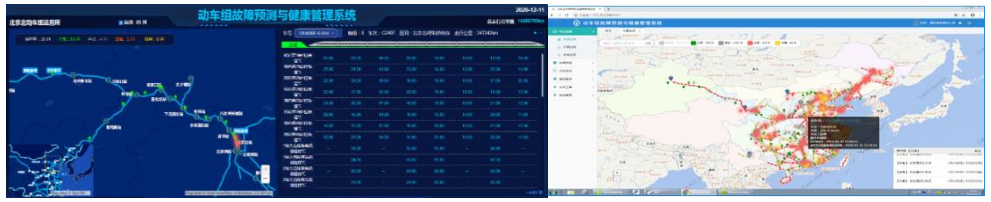


Intelligent Passenger Flow Density Analysis, etc.

Intelligent O&M



Integrated O&M of Track, Communication, Signaling, and Power Supply



Intelligent EMU O&M, etc.

3.4 经济社会效益Economic and Social Benefits

1. The premium quality of the intelligent Beijing-Zhangjiakou HSR has contributed to the success of the **2022 Beijing Winter Olympics**, fueling the **economic growth** of the adjacent regions.

2. Beijing-Zhangjiakou HSR makes travel more convenient for tourists as **it takes only a 31-minute train ride** from Beijingbei Railway Station to Badaling Great Wall Railway Station and then a 2-minute walk from the station exit to the scenic spot, **saving** more than **RMB 750 million** each year in terms of passengers' time value.

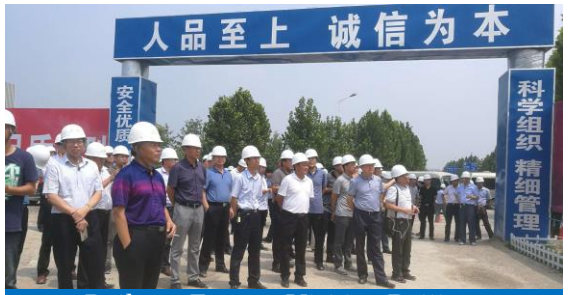
3. With the century-old cultural heritage of Beijing-Zhangjiakou Railway, the HSR line upholds the **development concept of "lucid waters and lush mountains are invaluable assets"**, and has realized both **cultural** and **environmental protection**.

4. The use of intelligent building technologies helps deliver **the opening of Beijing-Zhangjiakou HSR nine months ahead of schedule**, making it a **green, and energy-saving** project.

5. The groundbreaking intelligent HSR architecture proposed has been **adopted by UIC**, significantly **enhancing** the **international influence** of China's intelligent HSR.



Beijing-Zhangjiakou HSR Serving the 2022 Beijing Winter Olympics



Railway Experts Visiting Beijing-Zhangjiakou HSR



Reports of Mainstream Media

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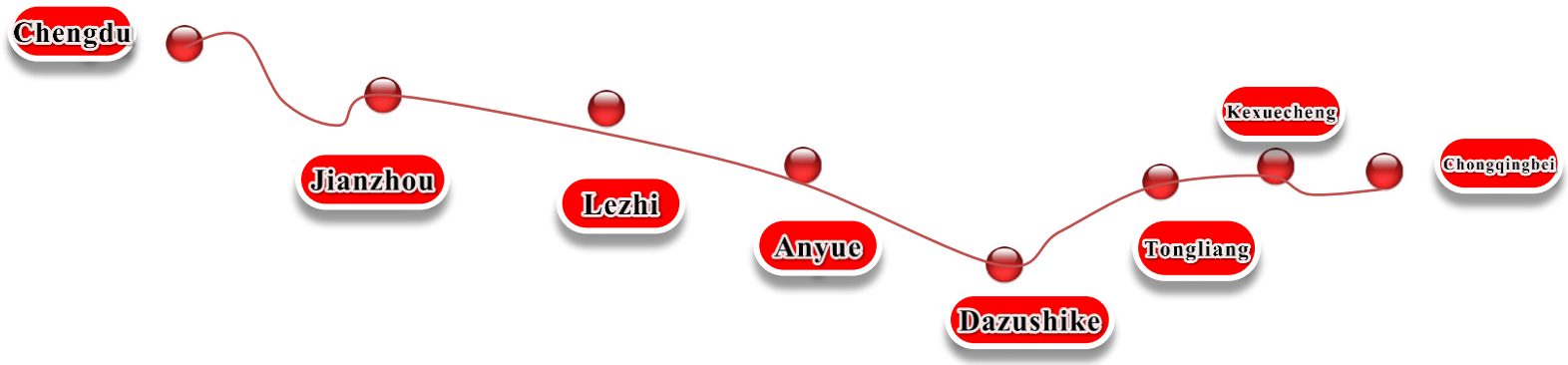
智能高铁发展展望 Exploration of the Intelligent HSR Development

Intelligent HSR 2.0 is a forward design of top-level system based on intelligent HSR 1.0 and aimed at optimal comprehensive system efficiency. It is to realize all-discipline collaboration and cross-sector integration, and promote the application of data analysis capabilities in predictive analysis.

lead Research Tasks

1. Intelligent engineering survey and generative design
2. All-discipline intelligent construction
3. Digital twin of railway engineering
4. CR450 intelligent EMU
5. Next-generation railway dedicated 5G mobile communication system (5G-R)
6. Operational safety protection based on multi-source information perception, transmission and fusion analysis
7. Maas+: End-to-End Intelligent Mobility Service
8. Intelligent integrated dispatching of regional railway networks
9. Wheel-rail integrated intelligent maintenance of EMU
10. Model-data Integration Platform

Middle Line of Chengdu-Chongqing HSR - A Demonstration Line of Intelligent HSR 2.0



*The main line is 292 km long
*the bridge-tunnel ratio is 85.52
* The design speed is 350 km/h
* The project is expected to be open to traffic by the end of 2027

Thank you for your attention.

Your feedback and comments are highly appreciated.

