System Safety Technology of China's High Speed Train

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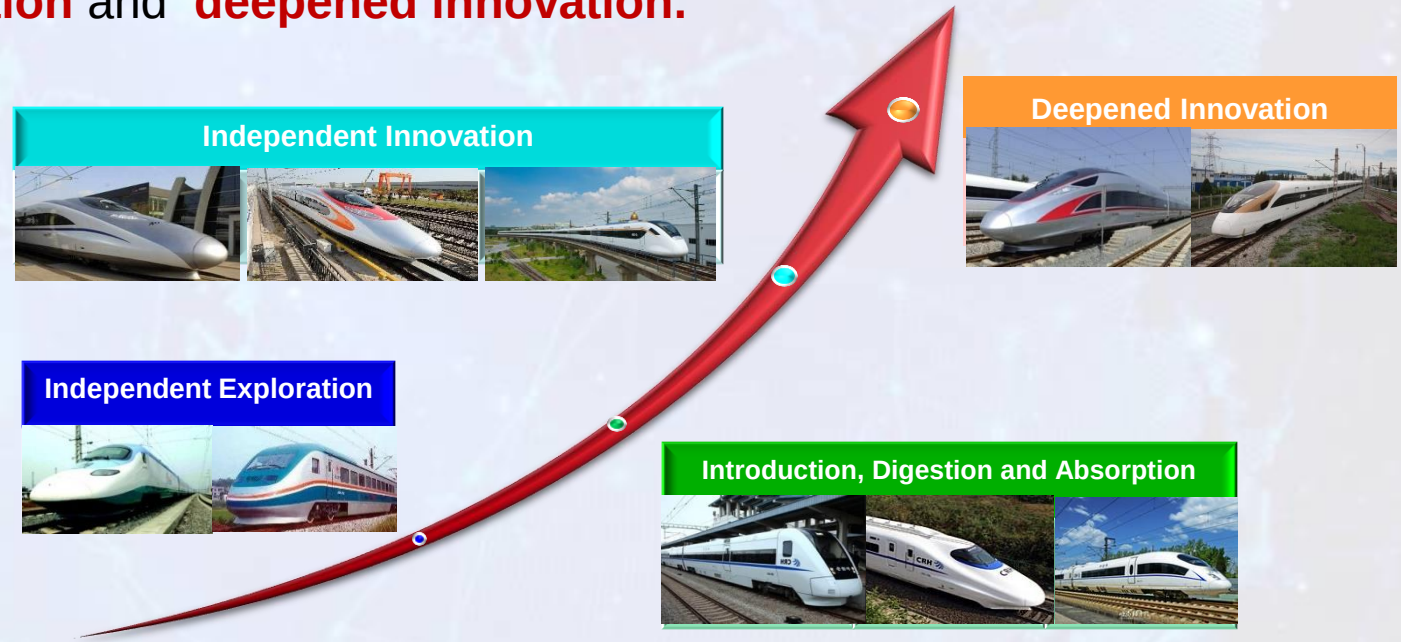
I. Achievements in China's HSR Development

As China HSR is developing rapidly, its high speed railway equipment represented by high-speed EMU become advanced in the world in terms of technology and development thanks to abundant practice in four stages, i.e. **independent exploration, introduction and digestion, independent innovation** and **deepened innovation.**



I. Achievements in China's HSR Development

1.Largest Operation Scale in the World

At present, a high speed railway network of four vertical and four horizontal lines has been build. 86 HSR lines with a total mileage of 22,000 kilometres have been put into service. There are 2,846 sets of high-speed EMUs in operation, with both the operating mileage and train inventory accounting for more than 1/2 of the world's total.

Japan – Radial Railway Network

Spain – Single Y-shaped Railway Network

HSR Networks in the World

Germany – X-shaped Railway Network

France – Double Y-shaped Railway Network

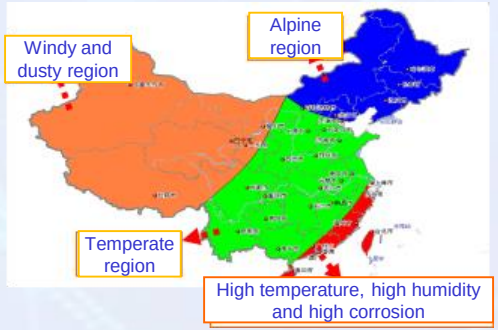
China's HSR Network

I. Achievements in China's HSR Development

2. Adaptability to Complicate Operation Environment

Boasting a wide adaptability, Chinese high-speed EMUs could accommodate to geographical，climate and complex interactions conditions as well as various operation scenarios.

Average failure rate of China's HSR is only 0.57 case per million kilometres.



Complex geographical and climate conditions

Plain, hill, mountain, plateau, etc.; - 40 ~ + 45 ℃, adapting to extreme low, high temperature and high humidity, able to withstand sand, wind, rain and snow erosion.

Complex operation scenarios

Passenger dedicated lines, upgraded existing lines and intercity lines, with heavy tasks and annual average operating mileage of 600,000km; long alignment (Beijing-Kunming Line of 2760 km); numerous tunnels (Wuhan-Guangzhou Line of 226 tunnels); altitude difference >3600m.

Complex interactions

Long formation, multi-body connection, high-speed operation, violent excitation by rail and other facilities, complex effects of vibration, impact and aerodynamics.

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I. Achievements in China's HSR Development

3. Full-fledged Product Family

A R&D platform that features genealogical products was established with 35 types of high-speed EMUs, covering the speed range from 160 km/h to 350 km/h for various environmental conditions. With different compositions and applications, these EMUs are serving in upgraded existing lines, intercity lines and passenger-dedicated lines.

Product Family of China's High-speed EMUs

Introduction & Digestion	Independent Innovation	Deepened Innovation
CRH1, CRH2, CRH3, CRH5 Series	CRH380 series, Intercity EMU series, Comprehensive Inspection Train	"Fuxing" EMU

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I. Achievements in China's HSR Development

4. World-leading Comprehensive Technical Performance

Outstanding performance indexes have been registered regarding operation speed, comprehensive riding comfort, safety, reliability, energy efficiency and eco-friendliness. Some of the technical indexes represent internationally advanced level.

Record-breaking running speed

Operating speed covering 200~350km/h Beijing-Tianjin, Zhengzhou-Xi'an, Wuhan-Guangzhou operating at 350km/h
Highest operation test speed of 486.1km/h created on Beijing-Shanghai railway line
High-speed trains meeting at 420km/h on Zhengzhou-Xuzhou railway line

Superior operating safety

486km/h derailment coefficient: 0.13<0.8
486km/h wheel unloading: 0.67<0.8
km/h wheel-rail lateral force: 15 kN<59kN
mergency braking distance: 4,850 m<6500m

Outstanding reliability

Failure rate per million kilometres is 0.57.

Leading overall ride comfort

350km/h ride quality: 1.82<2.5
350km/h comfort index: 1.66<2.0
350km/h saloon noise: 66 - 68dB(A)
<70dB(A)
350km/h interior pressure: Open line 86 Pa/3s
Tunnel 205 Pa/3s
<800Pa/3s

Remarkable energy efficiency and eco-friendliness

350km/h far-field noise: 93 dB(A)<94
350km/h running resistance: 64 kN
35km/h energy consumption per person: 3.7kwh/100km

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I. Achievements in China's HSR Development

5. Technical Innovation of "Fuxing" EMU

"Fuxing" EMU is a type of 350km/h EMU developed based on the operation demand in China under the leadership of China Railway Corporation. Its major features include:

- **Safety**: Higher critical instability speed; the train is equipped with derailment protection, earthquake early warning unit, bogie and real-time temperature monitoring.
- **Energy efficiency and eco-friendliness**: Innovative train nose and streamlined carbody design leads to 64kN train running resistance at 350km/h with energy consumption per person of 3.7kwh/100km, 12% lower compared with CRH 380A.
- **Comfort:** Low noise design; saloon noise is 66 ~ 68dB(A) at 350km/h, 3dB(A) lower compared with CRH380A; WIFI and ticketing system is provided to improve riding experience;
- **Interoperability** : EMU built by difference manufactures could be interoperated for multiple operation to increase utilization of trains.

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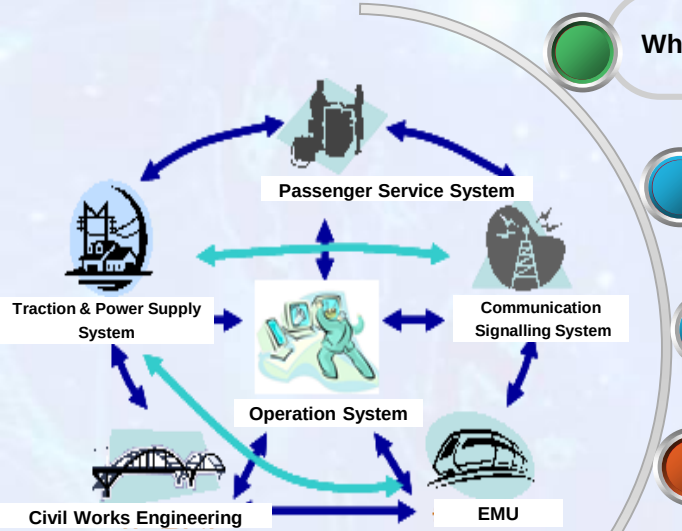
II. HST System Safety Technology

1. Challenges for HSR System Safety

Interaction among train, track, catenary and air flow become more intense during high speed operation, and comprehensive consideration needs to be taken in wheel-rail interaction, pantograph-catenary interaction, fluid-structure interaction as well as natural conditions for HST system safety.



- **Wheel-rail interaction: Typical track modal matching, dynamics.**
- **Train and power supply system: Pantograph-catenary matching, catenary voltage quality, switching over neutral sections.**
- **Train and operation control system: EMC, on-board interfaces.**
- **Fluid structure interaction: aerodynamic performance, distance between track centers, ground effect, impact on adjacent facility, trackside personnel safety.**
- **Natural conditions: ice, frost, rain, snow, air pressure changes, foreign matters intruding loading gauge.**

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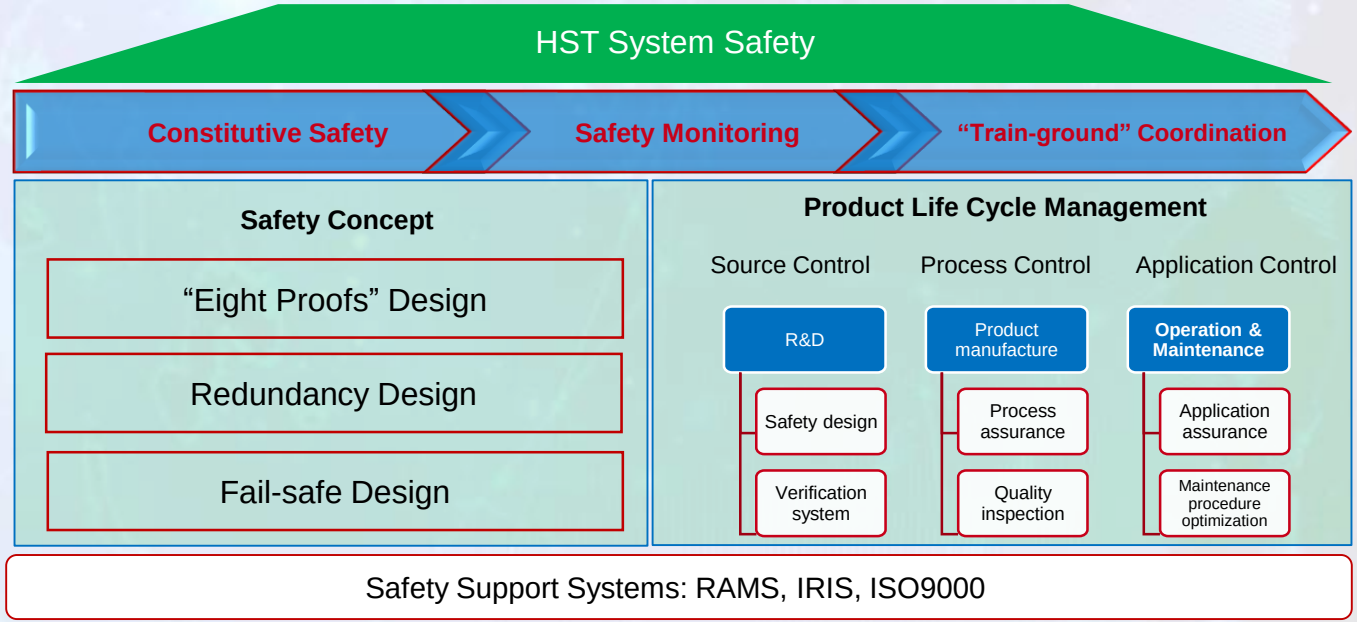
II. HST System Safety Technology

2. HST System Safety Technology Architecture

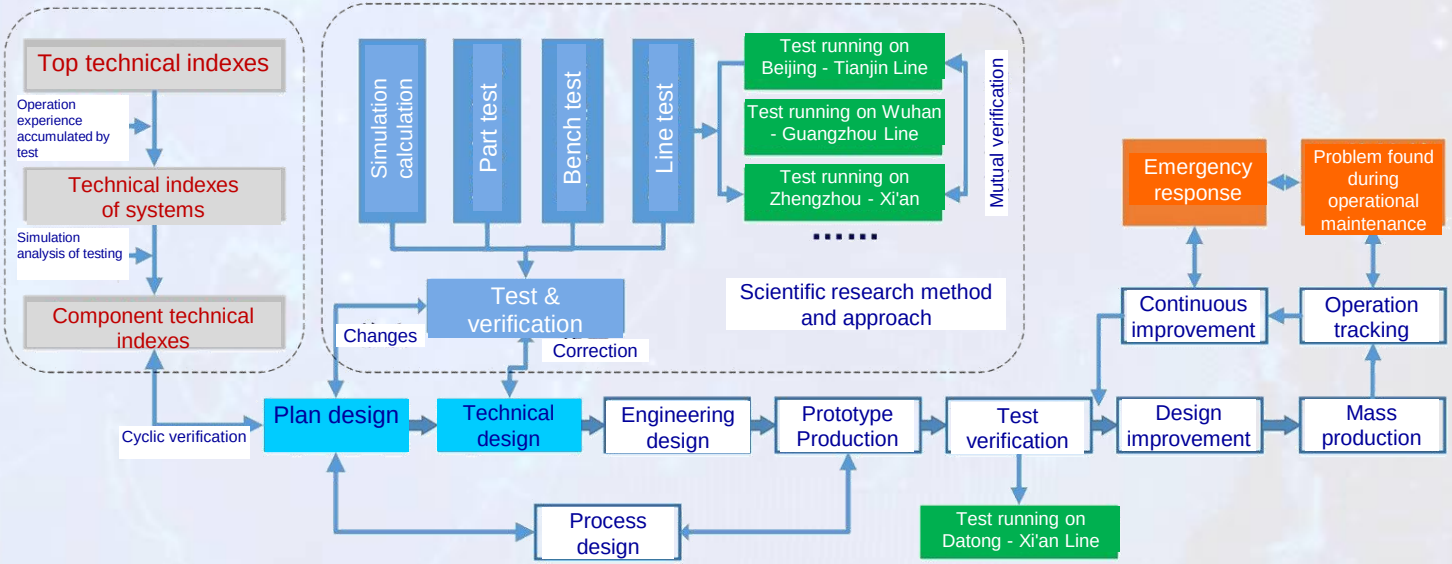
Centring on requirements of safety operation, a safety architecture is established to cover design, manufacture and application throughout life cycle of the products.



II. HST System Safety Technology

3. HST System Safety— Constitutive Safety

R&D Process：With safety and reliability at its core, quality of product design is ensured by means of top technical index breakdown and loop iteration.



II. HST System Safety Technology

3. HST System Safety— Constitutive Safety

Safety Management System: Safety elements and mechanisms of HST is systematically analyzed based on the operation features of HSR. A risk management database is established to control life-cycle system safety process covering design, verification, management and evaluation of products.

1	2	3	4	5
System Planning	**Safety Design**	**Safety Verification**	**Faults Zeroing**	**Third-party Assessment**
Establish a management organization for system assurance.	Carry out the RAMS analysis along with design from the aspect of failure/hazard, and develop the prevention/mitigation measures.	Conduct safety verification during vehicle development to demonstrate that the systems/equipment are designed to meet the safety requirements.	Establish FRACAS system to perform closed-loop zeroing management of faults.	Conduct independent safety assessment to assess vehicle safety at all stages of vehicle design and development.

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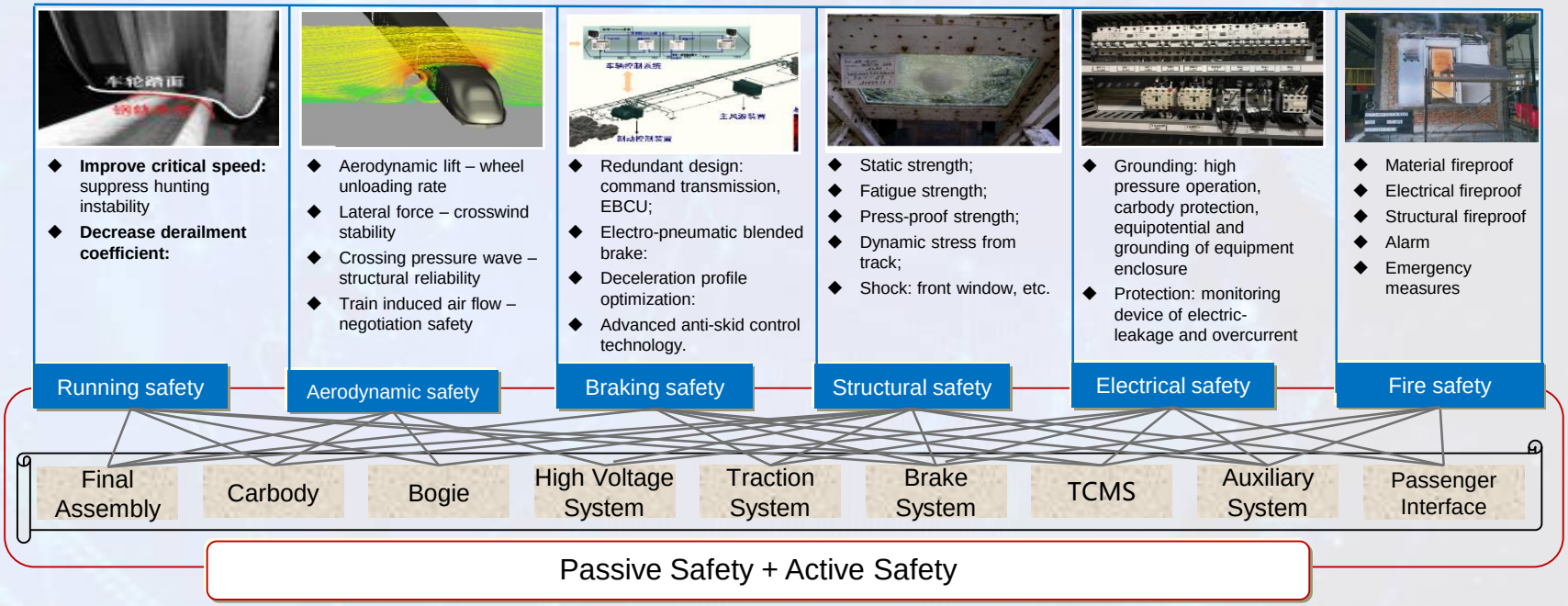
II. HST System Safety Technology

3. HST System Safety— Constitutive Safety

Safety Design: Safety design is made in combination with active and passive safety measures for key systems such as bogie, aerodynamics, brake system of the train.



II. HST System Safety Technology

4. HST System Safety— Safety Monitoring

Objective

Safe operation of train, human-machine interface management under different scenarios of operation and maintenance.

Principle

Categorized and tiered control is made on safety monitoring programs and safety measures according to the significance of safety hazards and their impacts on train operation order on a safety basis.

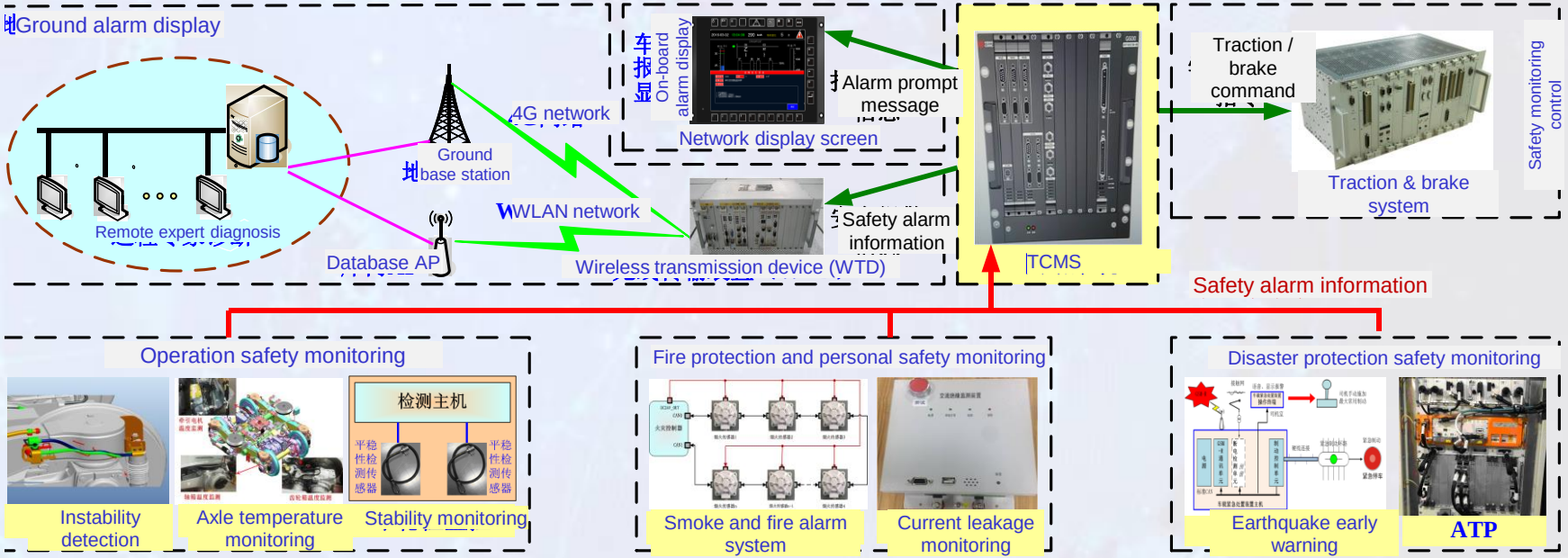
Scope

With respect to impacts on human, train and line operation, running safety monitoring of HST focuses on monitoring of running gear status, fire protection, human safety, etc.

II. HST System Safety Technology

4. HST System Safety— Safety Monitoring

TCMS and Various Levels of Control Systems: Various levels of safety alarming information is generated based on logical algorithm or diagnosis model with information collected by on-board sensors. Then TCMS and brake system will implement the protection functions such as alarming, automatic speed limiting and braking in corresponding levels.



II. HST System Safety Technology

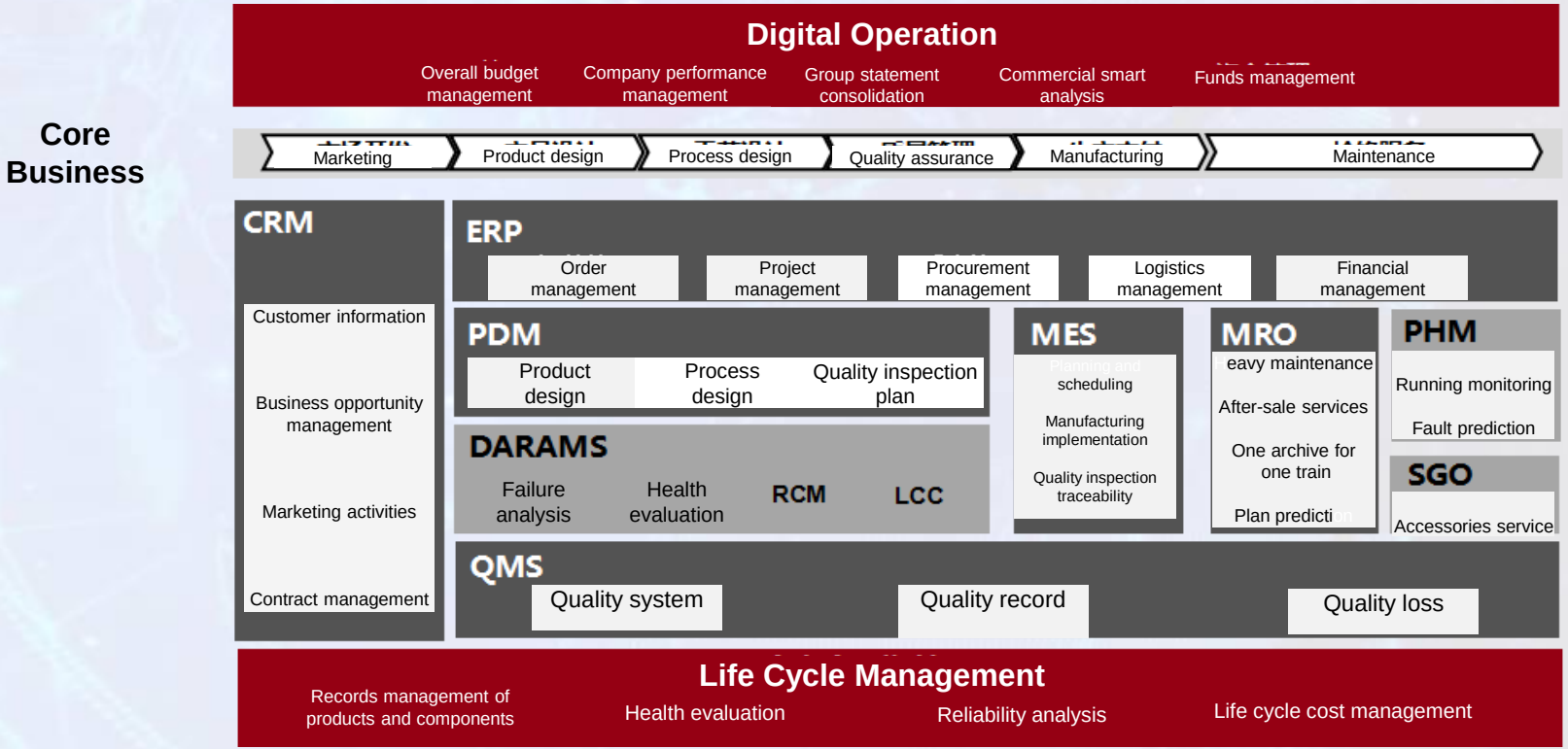
5. HST System Safety — Train-ground Coordination

System: Digital service for safe operation assurance is achieved by exploiting the real-time train operation data and life-cycle data covering design, manufacture and maintenance. An integrated operation and maintenance service system is developed with the mutual support of the manufacturer and the user by means of interconnection with the Operator through remote support center.

II. HST System Safety Technology

5. HST System Safety — Train-ground Coordination

Digitalization: With core business as its core, data flow is connected throughout life cycle of products covering R&D, procurement, manufacture and service.



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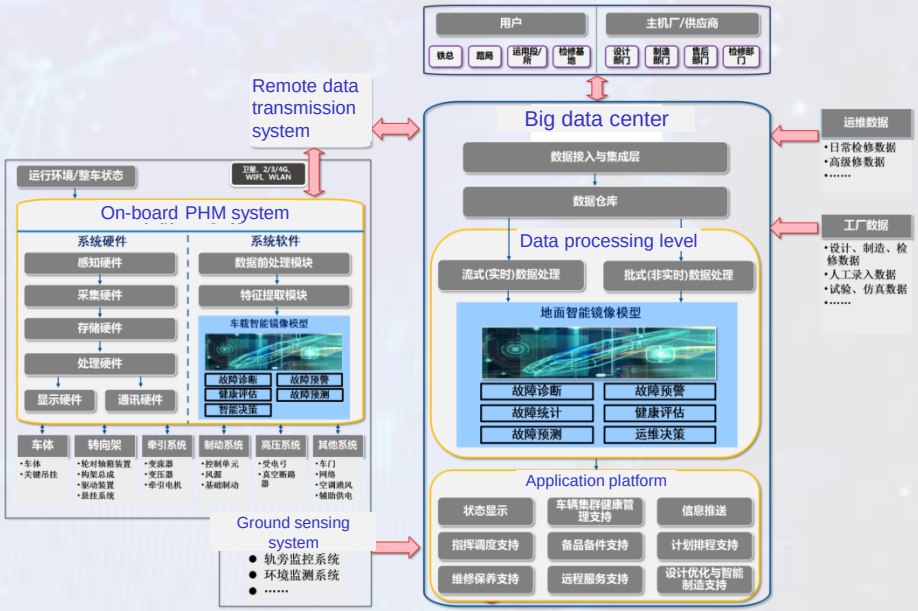
III. Development and Application of New Safety Technologies of HST

Larger quantity, broader operating regions, higher speed and new technologies such as digitization application in HST brings about new tasks for safety assurance.

1. PHM System Based on Big Data Application

Train operation and environment data is fully tapped by applying Big Data and concept of PHM to realize the intelligent self-diagnosis, performance self-evaluation and safety early warning of the train.

- **On-board PHM**: Sorting out safety-related failure risk items; analyzing failure mechanism; real-time monitoring and comprehensive diagnosis of train operation status.
- **Ground PHM**: Real-time monitoring of fleet, individual vehicle or components of sub-systems. Failure prediction, health monitoring, decision-making during operation and maintenance is made based on Big Data measures such as machine learning and deep exploiting.



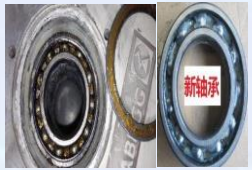
III. Development and Application of New Safety Technologies of HST

2. Application of New Safety Monitoring Technologies

Research of Safety Monitoring Based on Traction Data: Research is made on the trend of traction data changes during failures of key components of bogie to summarize the characteristics of data during failures, which could be used for anticipating early failures of traction and transmission systems.

Failure mode → **Simulation test** → **Extraction of failure model** → **Failure early warning**

Rotor wear, rotor eccentricity

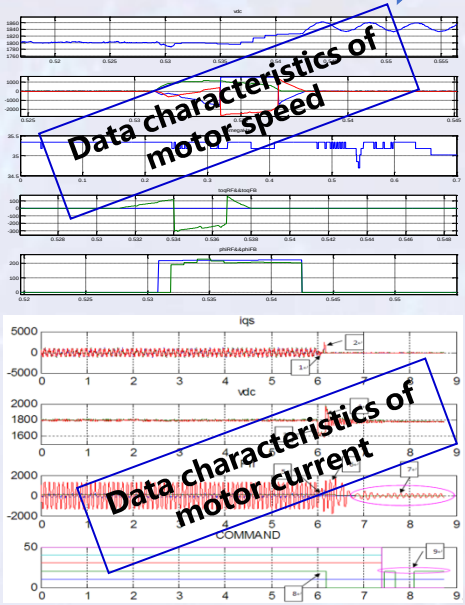


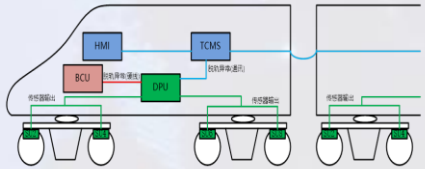
Bearing wear

Axle box and bearing separation

Vehicle Rolling Test Rig

Traction Simulation Test Rig





SU: Acceleration sensor of axle box body (1 per axle box)
DPU: Detecting host (1 per car)
BCU: Brake control unit
TCMS: Train Control & Management System
HMI: Human-machine interface

Driver and train staff will be alarmed for trouble shooting once failure of component is detected.

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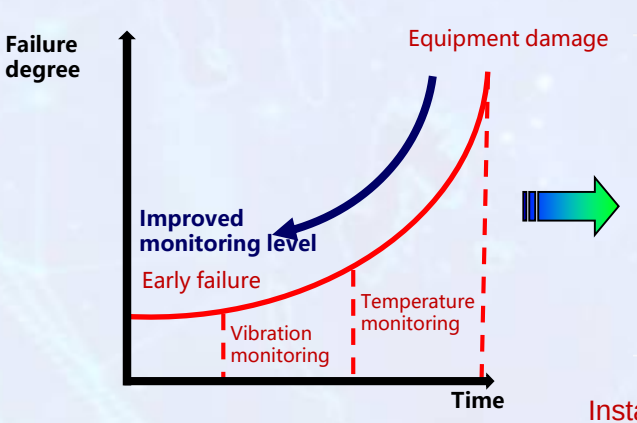
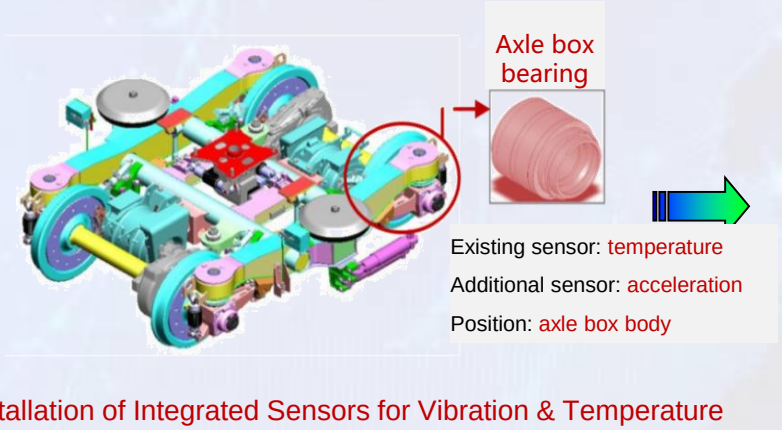
2. Application of New Safety Monitoring Technologies

Integrated Monitoring of Vibration and Temperature: Vibration monitoring of unsprung components is added in addition to temperature monitoring to identify early minor failure characteristics of rotating parts, improving the train safety monitoring and expanding the scope of safety inspection.





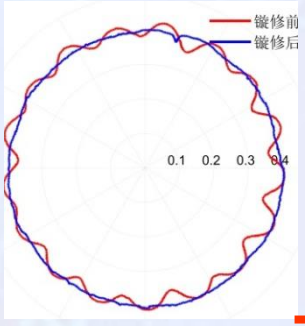
Installation of Integrated Sensors for Vibration & Temperature

- Health status of bearing
- Wheel roundness evaluation
- Foreign object hitting
- Derailment trend detection
- Wheel off-track detection

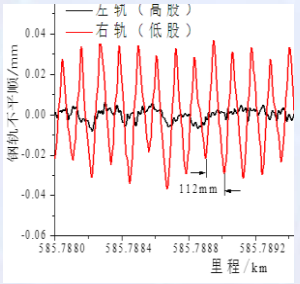
2. Application of New Safety Monitoring Technologies

Wheel Out-of-round and Rail Corrugation: Research is made on the forming mechanism of wheel polygon and rail corrugation, and monitoring of wheel roundness and shortwave irregularity of rail is conducted for abnormal conditions of wheels and rails to reduce the vibration of running gear, improving the structural running safety.

Wheel Polygon



Rail Corrugation



Application of New Technologies

- Wheel-rail Force Monitoring
- High-frequency Vibration Monitoring
- Noise Monitoring
- Regular Wheel Roundness Test

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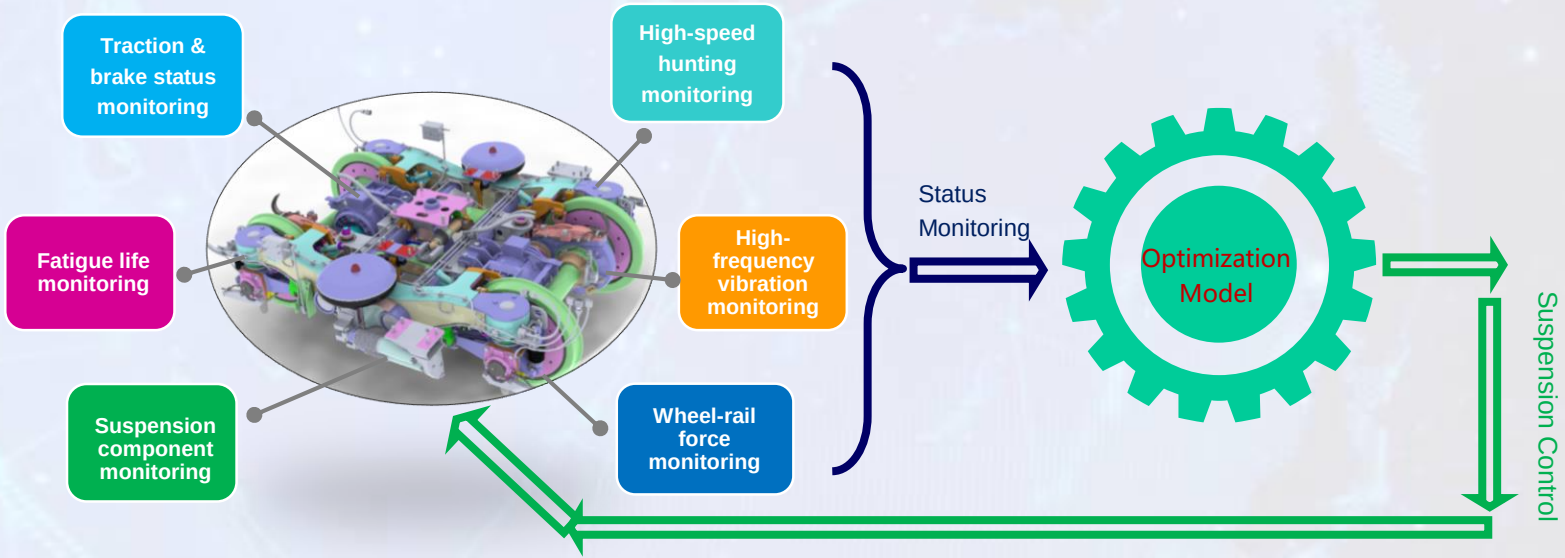
3. Intelligent Train-track Status Real-time Diagnosis System

Research is made on key technologies of intelligent bogie to acquire information of components running status, loading conditions and health level. Real-time diagnosis system for train-track status is developed with combination of the train operation safety monitoring system to improve the running safety of the train.

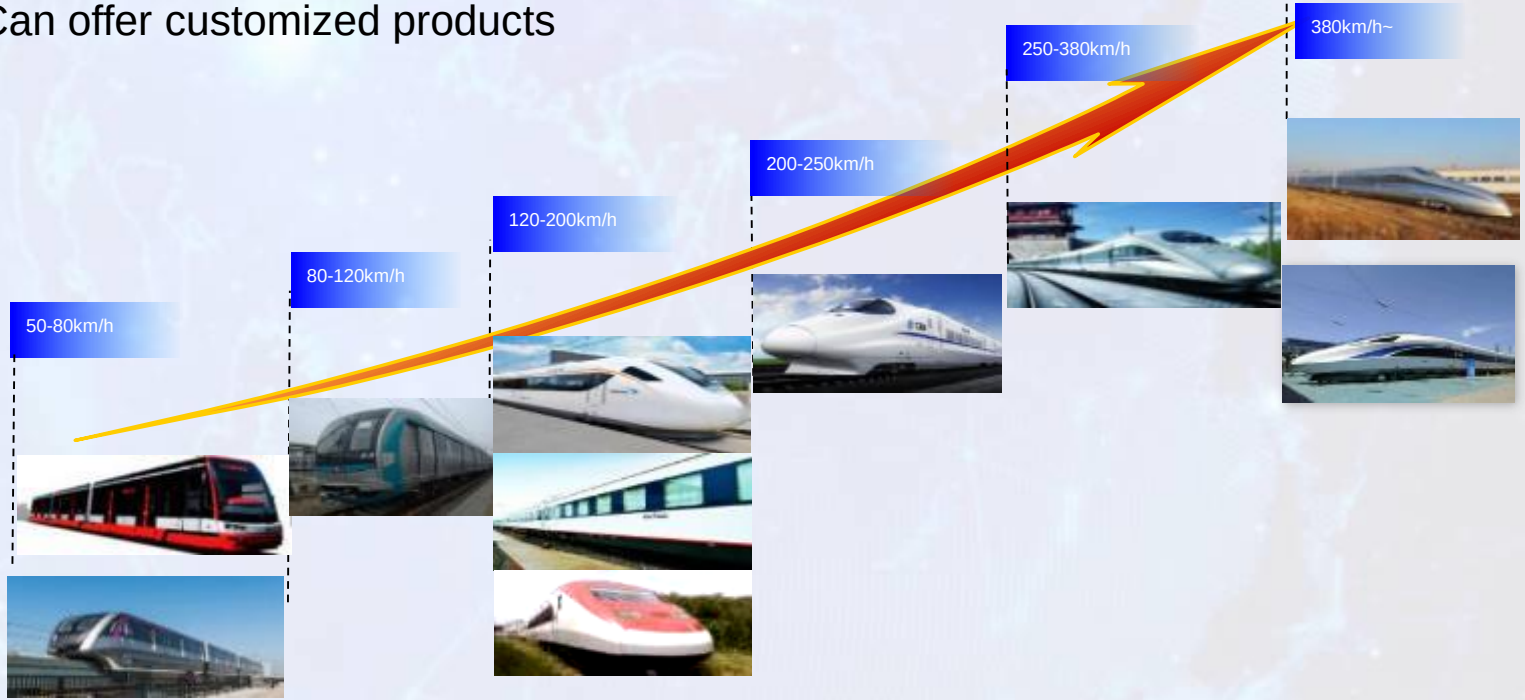


III. Development and Application of New Safety Technologies of HST

Safety of high-speed train holds the key to high speed railway development. With numerous new materials, information technologies and digital technologies, safety technologies of high speed train will continue to be improved. We truly wish to strengthen cooperation with organizations from all walks of life to promote the development of safety technologies of high speed train from status monitoring, device safety and equipment safety to failure prediction, sub-system safety and ecosystem safety.

III. Development and Application of New Safety Technologies of HST

- Able to provide life cycle system solutions including R & D, manufacture, maintenance and LCC etc.
- The seven products platforms ,High Speed EMUs, Intercity EMUs, DMUs, High-grade Railway Passenger Coaches, Metro Vehicles, Low Floor Trams, and Monorail.
- Can offer customized products



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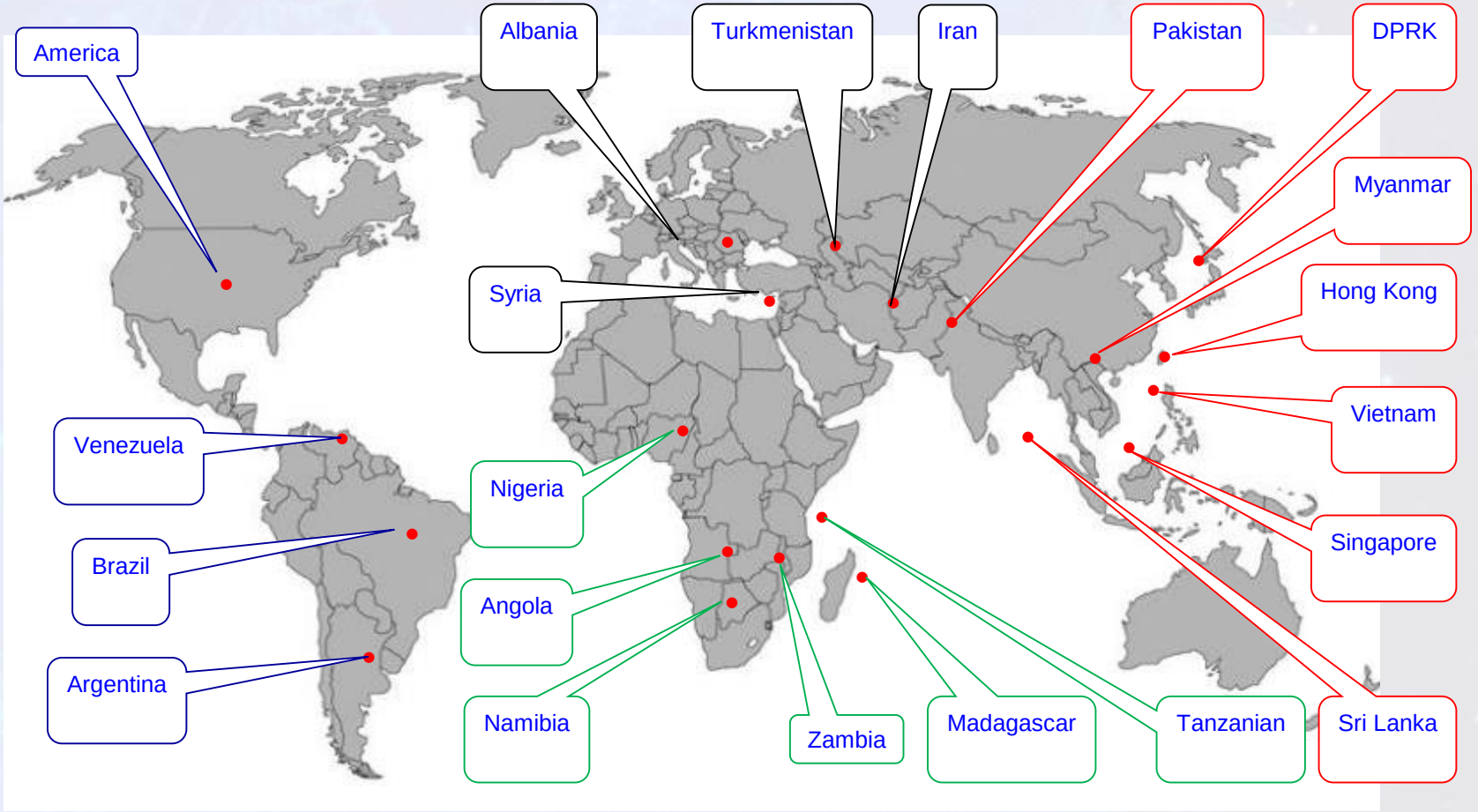

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