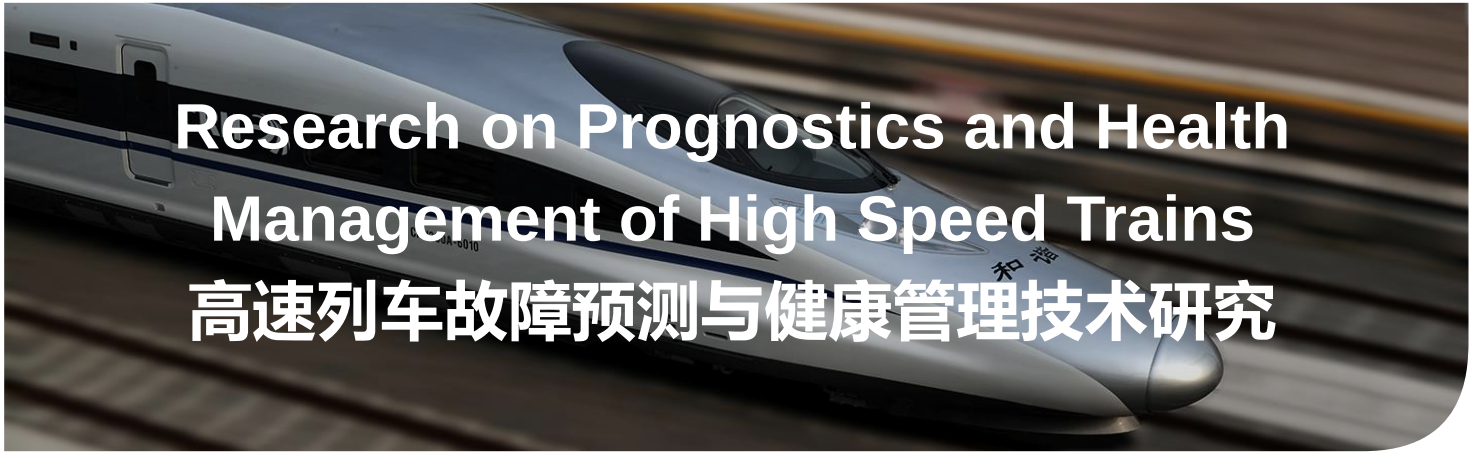
中国中车 CRRC



Research on Prognostics and Health Management of High Speed Trains
高速列车故障预测与健康管理技术研究

张 志 强　　Zhang Zhiqiang

中车青岛四方机车车辆股份有限公司

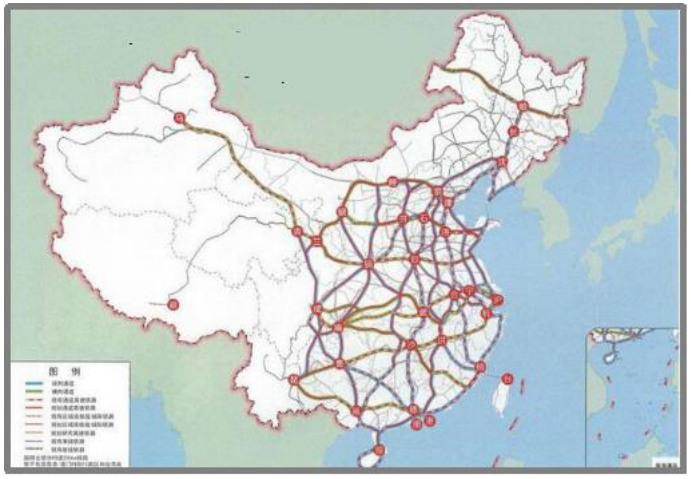
CRRC QINGDAO SIFANG CO.,LTD.

October 2017

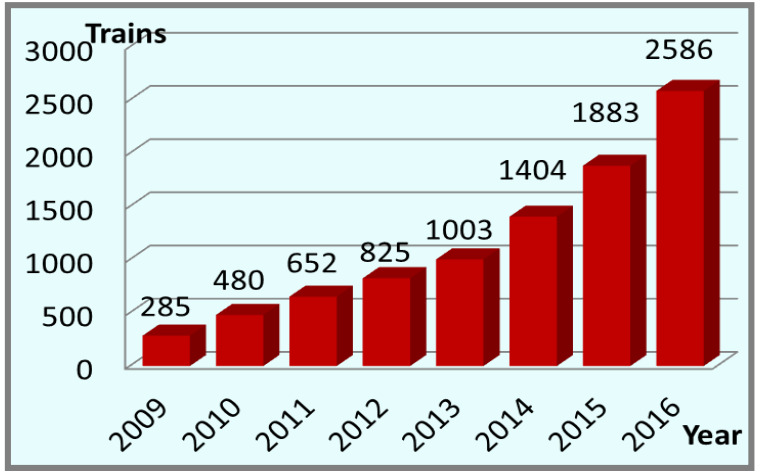
Outline

CRRC

Project Background



Medium-and long-term planning for China's high-speed rail network



Increase of EMUs between 2010 and 2016

How to ensure the **operation safety** and to improve the **operational efficiency** has received high level concern.

High Challenge for Operation and Maintenance

CRRC

Introduction of CRRC PHM Projects

The PHM Project at CRRC QINGDAO SIFANG:

- Objective: Develop a PHM system for EMUs to transform the maintenance paradigm from preventive to predictive maintenance

- Year of start: 2016

- Project goals:
  - Strengthen operation safety
  - Improve operation efficiency and reduce maintenance costs
  - Provide after market service to enhance competitiveness
  - Enable worry-free experience for end users

Challenges for PHM in High-speed Rail

We have seen the following challenges in PHM development for EMUs:

Challenge	Impacts
Large number and distributed fleets	• Data communication challenges • Peer variance
Multi-component and complicated systems	• Too costly to build expert system and physical model for each component
Multiple and continuously varying operation regimes	• Machine learning and data-driven PHM techniques have to deal with complicated patterns

CRRC

Outline

Prognostics and Health Management

Enhanced Diagnostics: the process of determining the state of a component to perform its function(s), high degree of fault detection and fault isolation capability with very low false alarm rate.

Prognostics: actual material condition assessment which includes predicting and determining the useful life and performance life remaining of components by modeling fault progression.

Health Management: is the capability to make intelligent, informed, appropriate decisions about maintenance and logistics actions based on diagnostics/prognostics information, available resources and operational demand.

Prognostics and Health Management

KEY TECHNOLOGY of PHM

- Sensing
- Data Analysis
- Health Assessment
- Performance Prediction
- Information Visualization
- Maintenance Strategy

According to the statistics of **IMS**

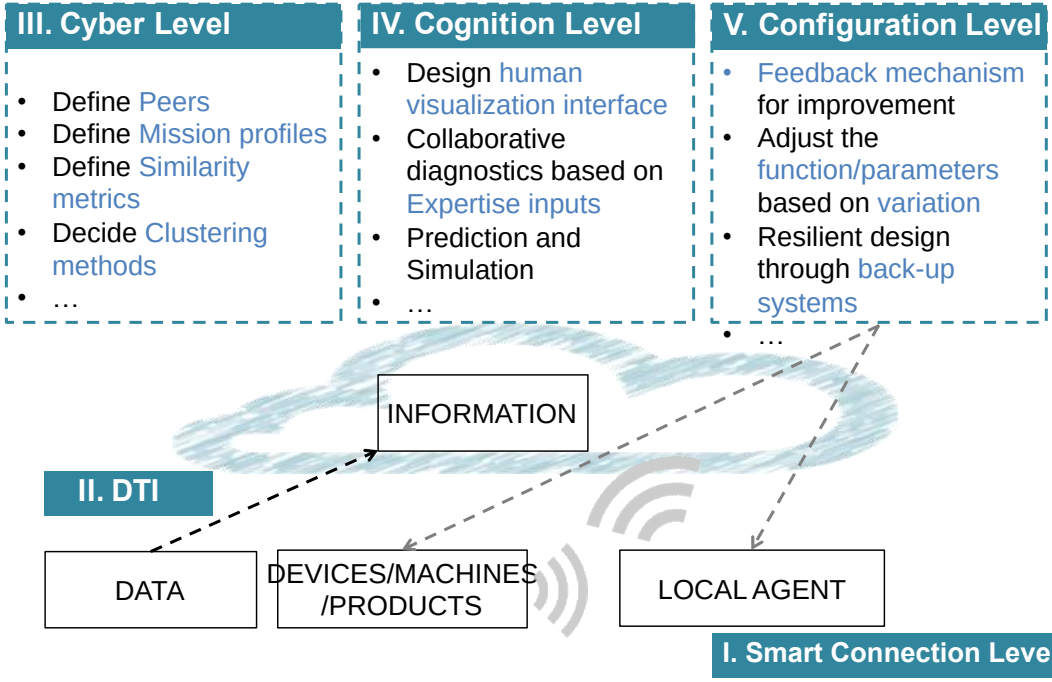
- Industrial operation ability **2.5%-5%** ↑
- Accident failure rate **75%** ↓
- Equipment maintenance cost **25%-50%** ↓

About Cyber-Physical System (CPS)

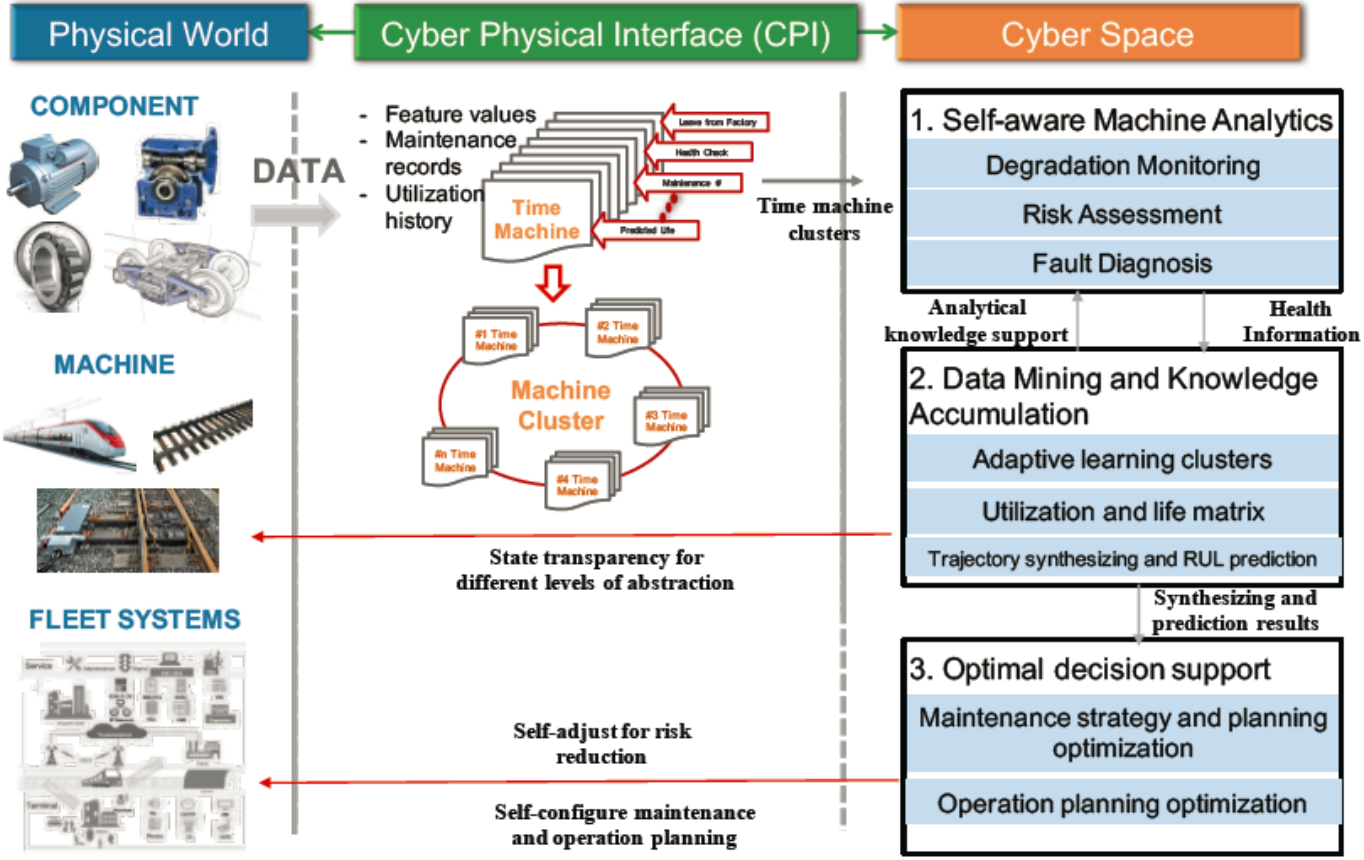
- Definition:

  Cyber-physical systems (CPS) are engineered systems that are built from, and depend upon, the seamless integration of computational algorithms and physical components.

- 5C Architecture for CPS Implementation (*Lee et al.*, 2013)



Predictive Analytics Interface based on CPS



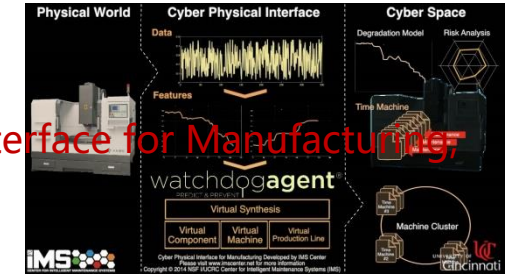
Source: IMS

CRRC

Cases for application of CPS and PHM

- CPS/PHM ----**Manufacturing Industry** (IMS Center)

Digital Twin for Machine Monitoring - Cyber-Physical Interface for Manufacturing, IMS Center

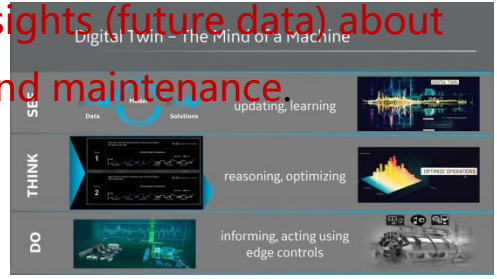


- CPS/PHM ----**Marine Industry** (Rolls-Royce)

With the aim of creating an open source digital platform for use in the development of new ships

- CPS/PHM ----**Wind Power Industry** (GE)

Digital twins offer (past data), KPIs (present data), and insights (future data) about an asset or system, from design and build to operation and maintenance.

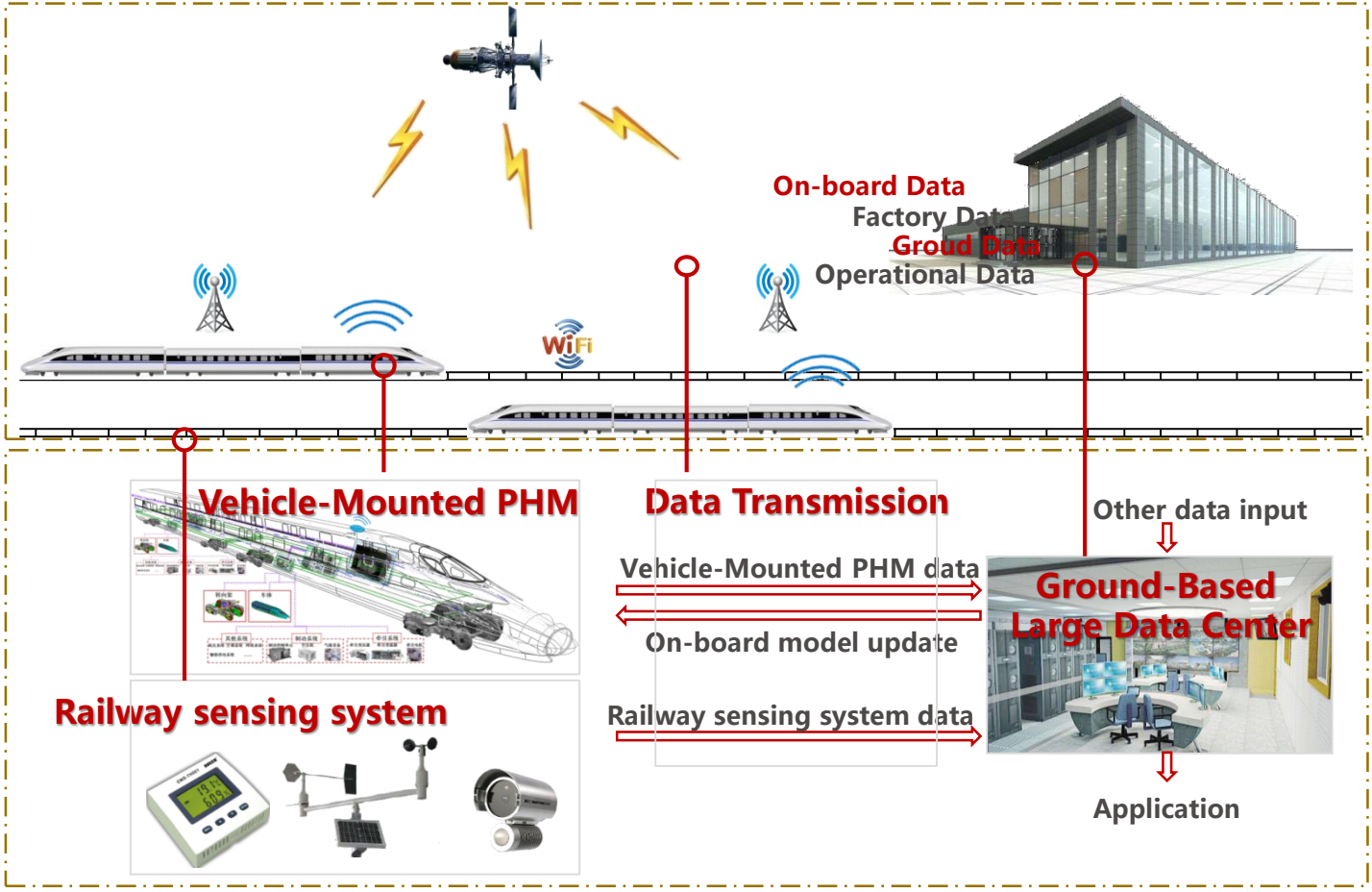


CRRC

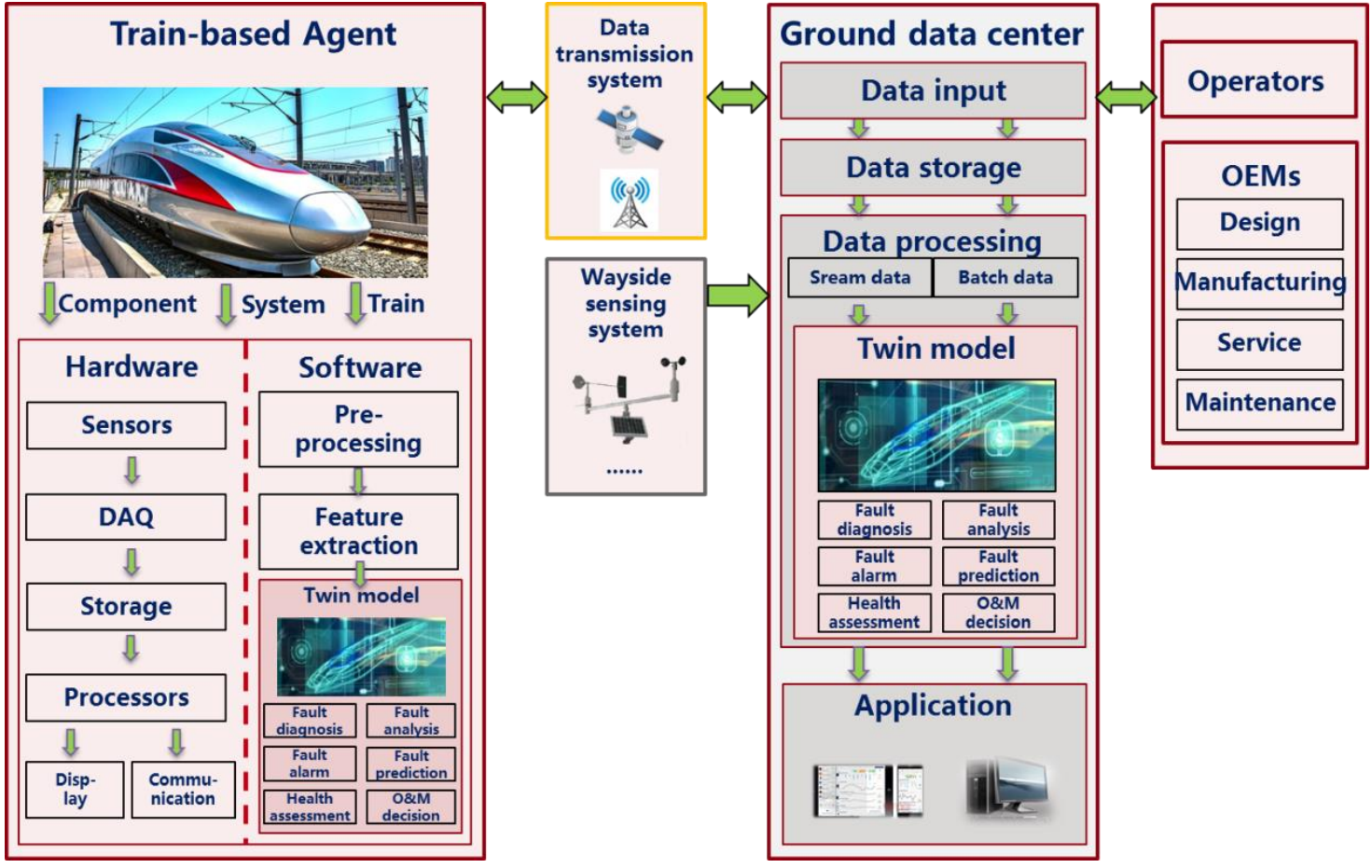
Outline

CRRC

PHM Framework designed based on CPS

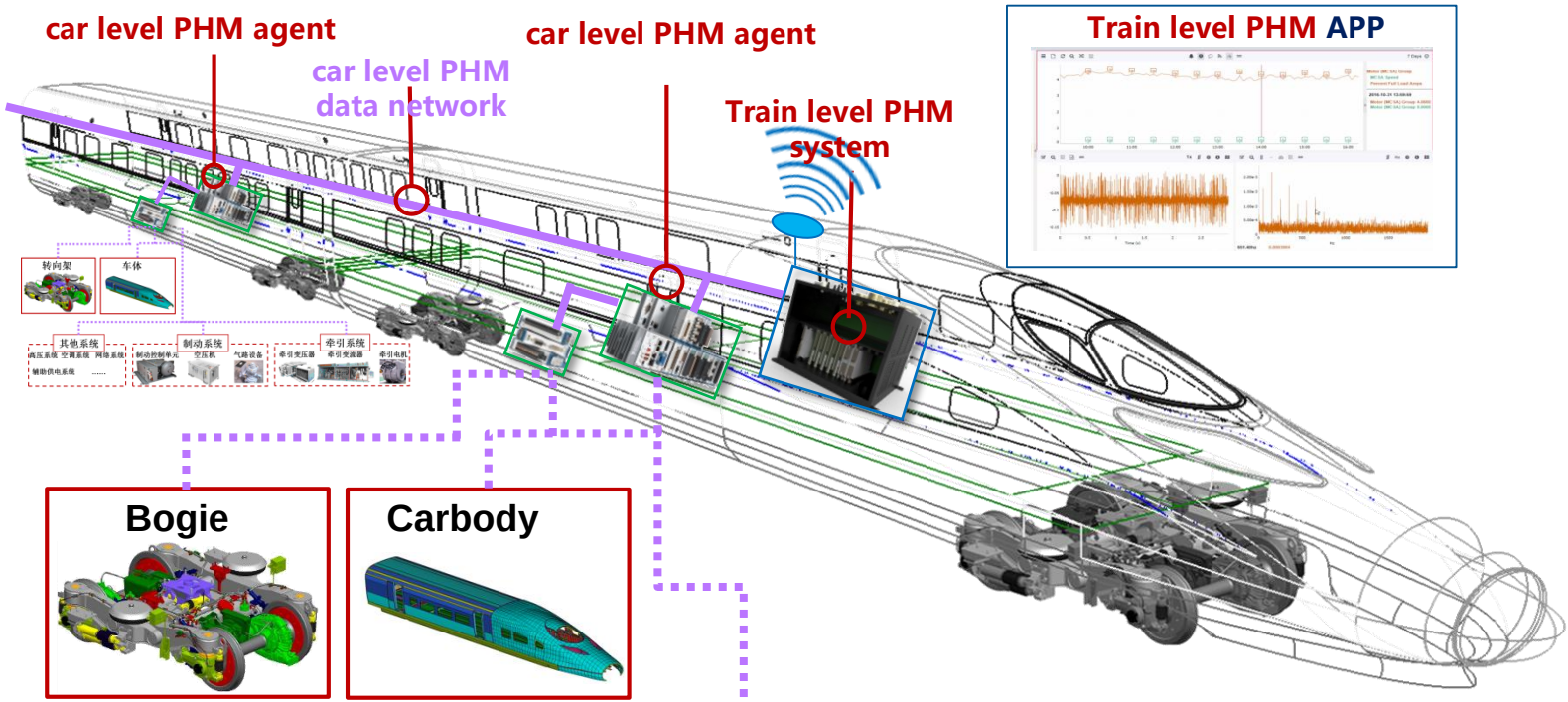


PHM Framework designed based on CPS



CRRC

The On-board PHM System for High-speed Train



Other system

- Air Conditioner
- Network System ……

Brake sytem

Control Unit

Air compressor

Traction system

Ttransformer

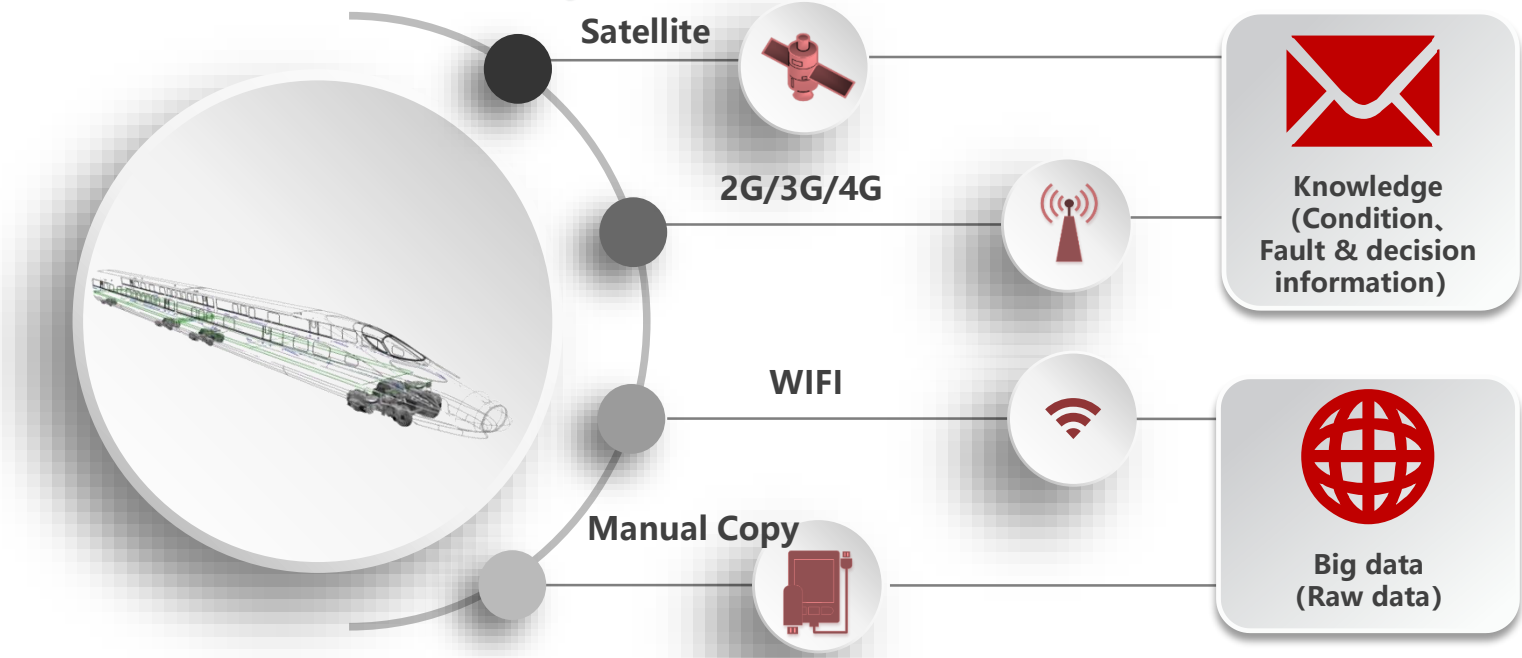
Converter

Motor

CRRC

Design of Data Communication System

Data Transmission System



■Real-time data transmission

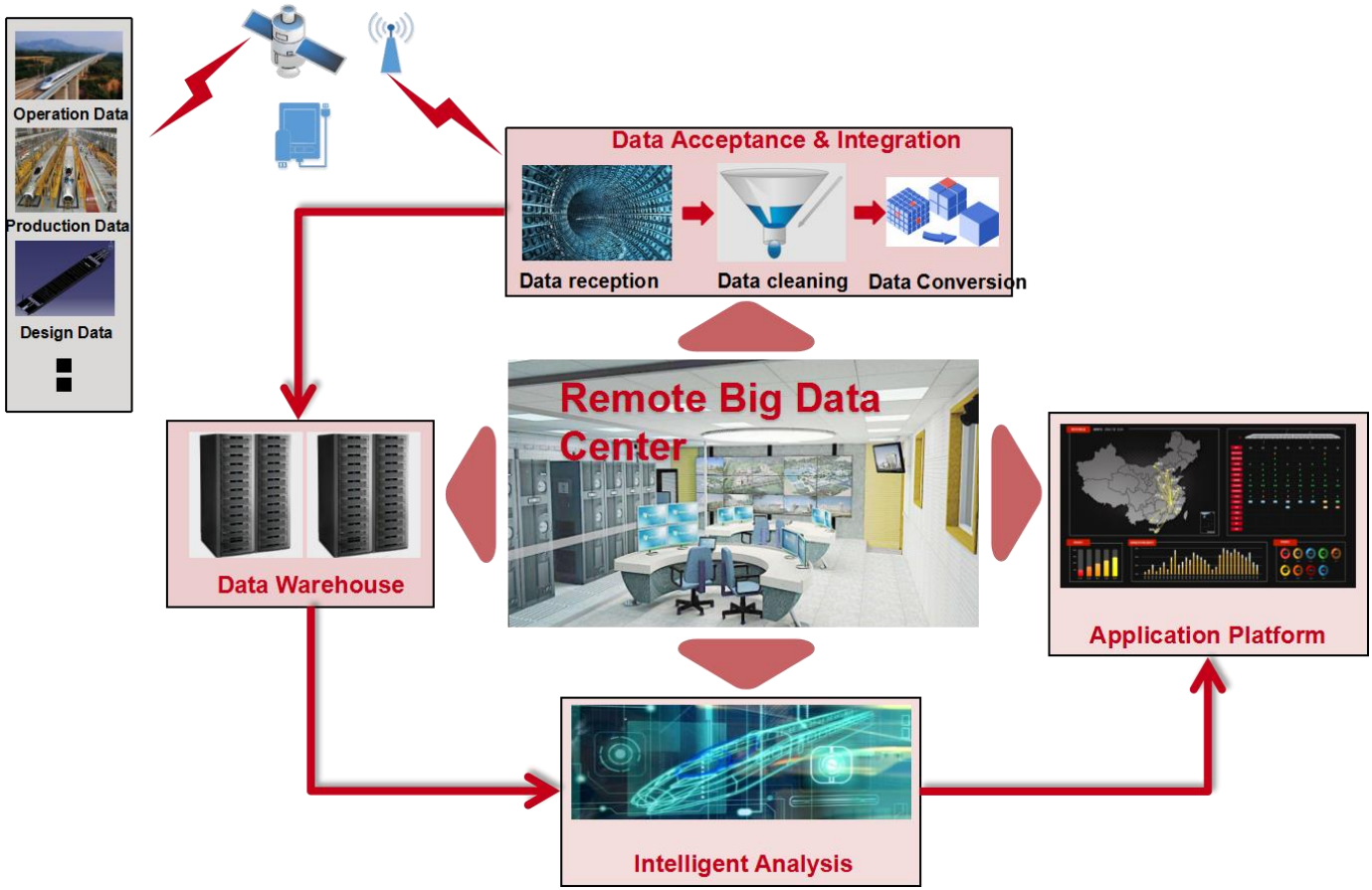
- 2G/3G/4G
- Dedicated industrial satellite (future)

■Raw data transmission

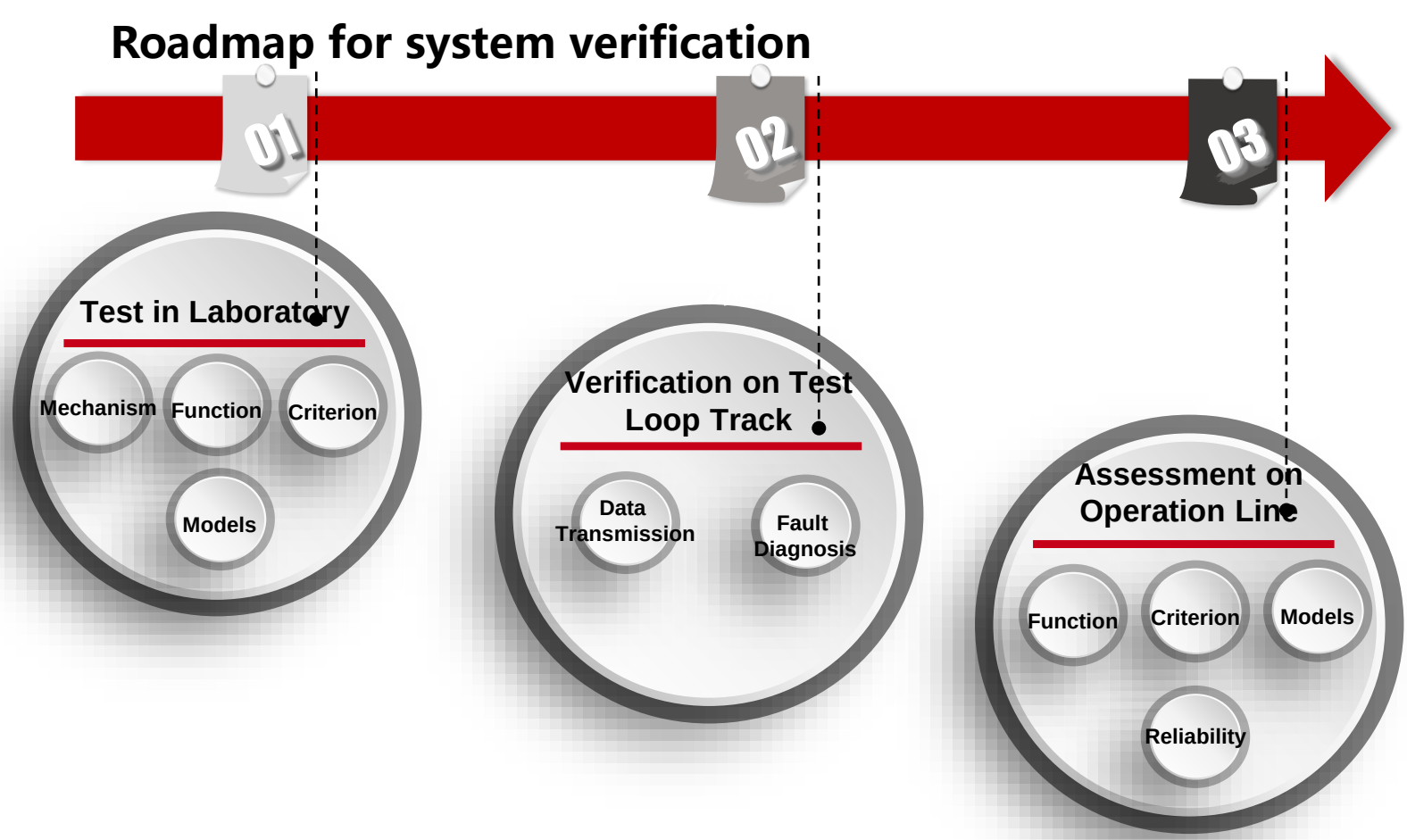
- WIFI at station
- Manual copy during daily inspection

PHM Framework designed based on CPS

- **Remote Big Data Center**



PHM Framework designed based on CPS



CRRC

PHM Framework designed based on CPS

Ground test platform

Test Bench for Vehicle Rolling Performance

Test Bench for train's Vibration Simulation

Test Bench for Carbody Strength

Test Bench for Structural Fatigue

PHM Framework designed based on CPS

Capability for Integrated Line Test

Dynamic Test Line

Line Test

Dynamic Test

In-car Vibration Test

Outline

Bearing Test Plan in CRRC Qingdao Sifang

600 Km/h Roller test-rig for bearing of various failure modes

Bearing accelerated damage test

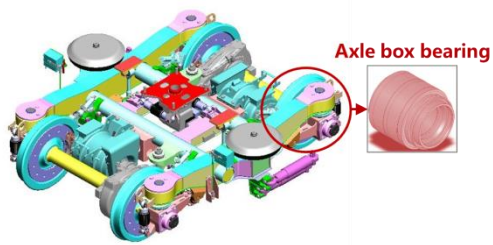
Testing track for bearing of various failure modes

Validation on Operation line

Roller Test-rig for Various Failure Modes

- Test-rig: The 600 Km/h Roller test-rig can simulate real track profile and test real scale train up to 600 Km/h

Test rig

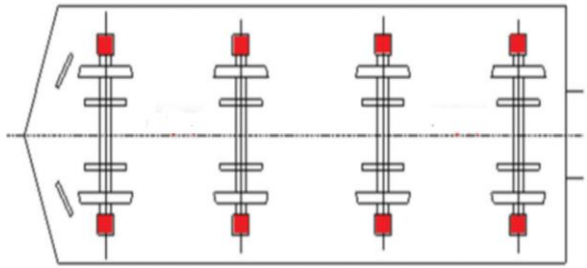


- Selected bearings

	Failure Mode	Failure Location
1	normal	
2	peel	Outer
3	dent	Outer & roller
4	corrosion	Outer & roller

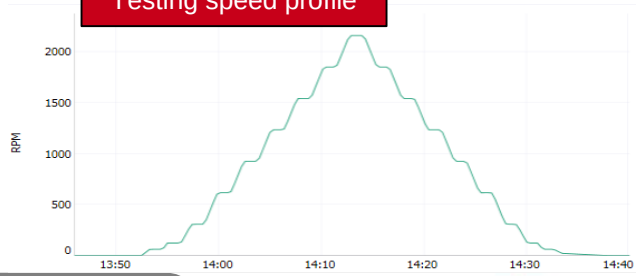
	Failure Mode	Failure Location
5	normal	
6	dent	Roller
7	peel	Outer
8	corrosion	Outer & Cage

Bearing Locations



- Testing Profile was 0-350 Km/h with 20 regimes for:
  - Accelerating
  - Constant speed
  - Decelerating

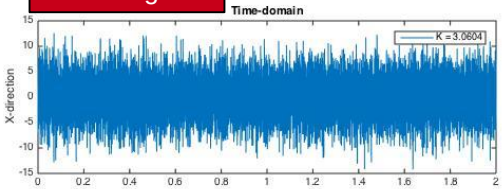
Testing speed profile

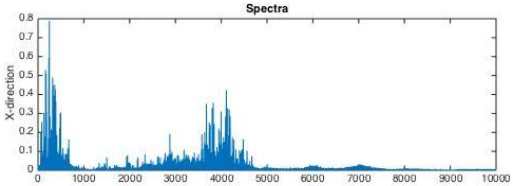


CRRC

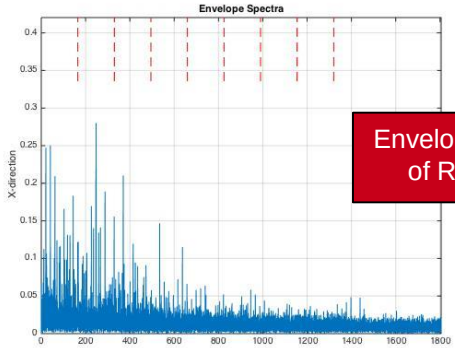
Initial Analysis Results for Constant Speed

Raw Signal



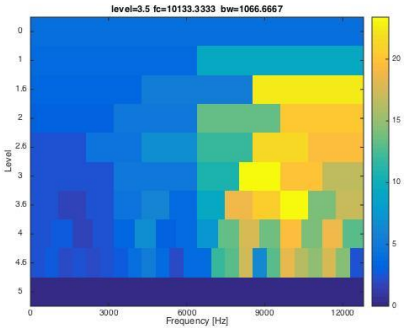


Hilbert Transform

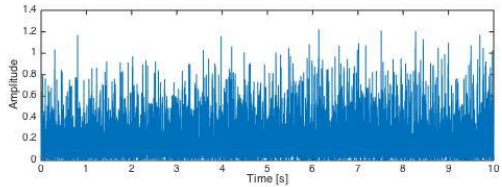


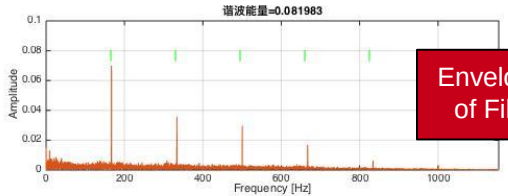
Envelope Spectrum of Raw Signal

Harmonic density centered filter band search



Hilbert Transform





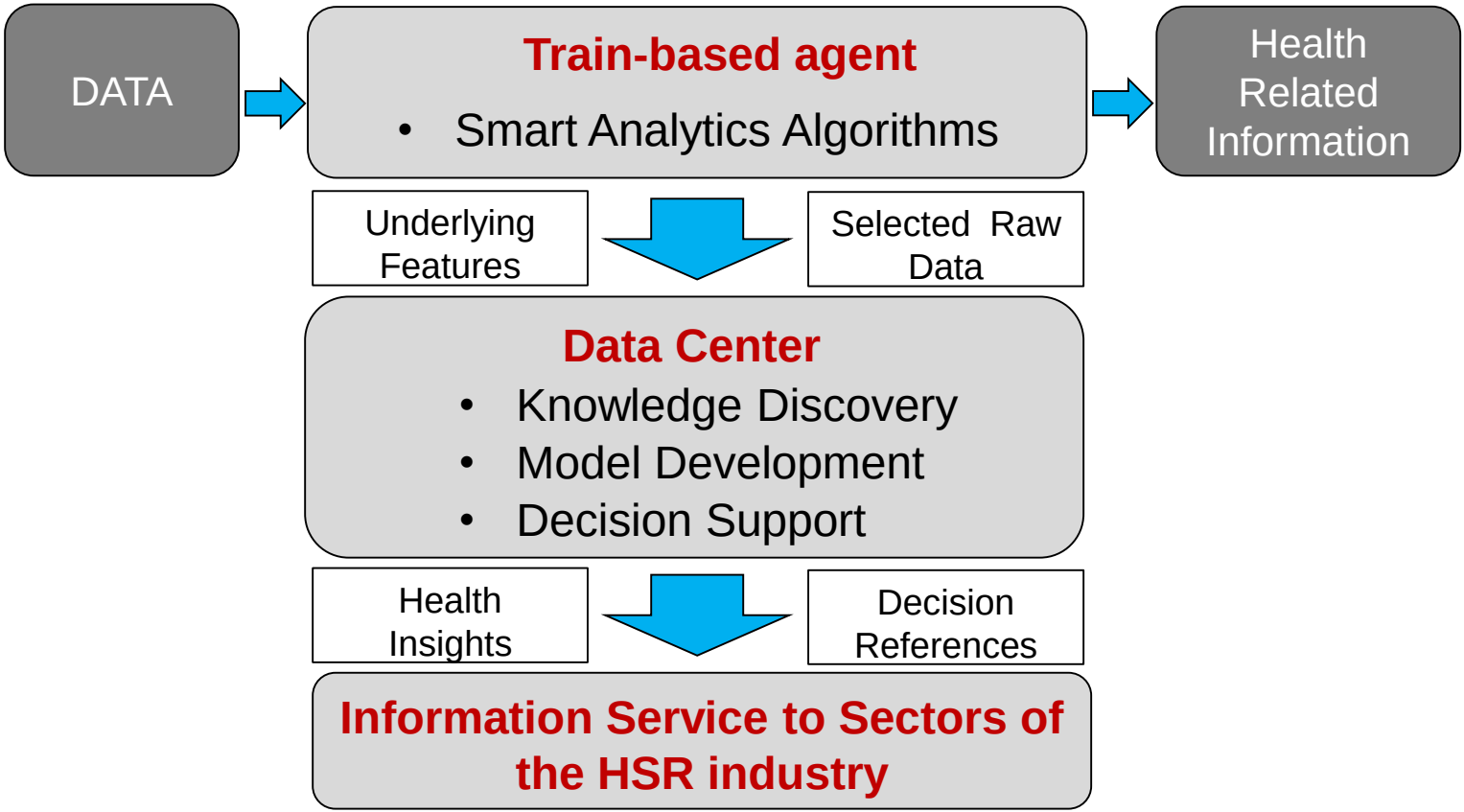
Envelope Spectrum of Filtered Signal

CRRC

Outline

Conclusion

Requirements & challenges in large fleets and big data environment



CRRC

Conclusion

Significance for Vehicle Operation Department

- Improve O&M cost with predictive maintenance plans
- Improve inspection efficiency by providing diagnosis information and decision support for users

Significance for Passengers

- Improve security experience
- Improve comfort experience

中国中车
CRRC

Thank you for attention !