The history of Shinkansen rolling stock for JR East started with the series 200 Shinkansen, which debuted at the opening of the Tohoku/Joetsu Shinkansen in 1982 in the Japanese National Railway era. It was initially a 12-car all motor car train with a maximum operating speed for 210 km/h.

The Shinkansen network spreading out in five directions later came to have a variety of forms of operation (Fig. 1); and even after the series 200, Shinkansen rolling stock conforming to those forms of operation and with increased speeds was developed. In addition to the standard type of Shinkansen dedicated rolling stock, others appeared such as rolling stock for through service between Shinkansen and conventional lines to Akita and Shinjo and double deck rolling stock for large-volume short-distance transport. A variety of services came to be provided as well, such as GranClass providing a higher level of service and fun-to-ride “Toreiyu” and “Genbi Shinkansen” (Fig. 2).

The Shinkansen, handling long-distance transport, has been forced to compete with airlines and others with the expansion of the Shinkansen network. In order to have customers choose the Shinkansen, we need to think up how to make it more attractive and amenity-rich. We need to make the Shinkansen something people want to ride by means such as shortening travel time to customers’ destinations by increasing speeds, improving amenity with better ride comfort and comfortable cabin environments, and providing functional services according to individual customers’ demands.

Looking at high-speed railway trends around the world, we see that many countries have achieved commercial operation in excess of 300 km/h, and Italy has announced further speed increases with a goal of 360 km/h commercial operation. And for JR East to transfer high-speed railway technologies abroad, we need to accumulate technologies for high-speed running in order to maintain competitiveness.

In the midst of this situation, JR East is constantly developing Shinkansen rolling stock systems utilizing new technologies in order to provide comfortable, safe, and highly reliable Shinkansen rolling stock that will please customers.
This article gives an overview of high-speed rolling stock development up to now and introduces technical development for future Shinkansen rolling stock.

2.2 FASTECH Project

Fig. 4 shows the development concepts for test vehicles in the FASTECH project.

The FASTECH360 trains were developed under the concept of being a "prototype for rolling stock operating at 360 km/h", a "test platform to identify phenomena when running at high speed" and a "near future comfort mobility space proposal stage". They are prototype vehicles for verifying technologies ahead of implementation in next-generation rolling stock in service. Two trains were produced: FASTECH360S (hereinafter, the "360S") exclusively for Shinkansen lines and FASTECH360Z (hereinafter, the "360Z") for through service on Shinkansen and conventional lines (Fig. 5).

Fig. 5 Shinkansen High-speed Test Trains (FASTECH360)

Being test trains, technical development went forward on four technical themes with a goal of maximum commercial operating speed of 360 km/h: Improvement of running speed, ensuring safety and reliability, consideration for the environment, and improvement of passenger comfort.

Wayside equipment was also improved along in line with production of test trains. Running tests were conducted from 2005 to 2009 to comprehensively evaluate and verify rolling stock and wayside facilities in the environment of the target commercial speeds.
2.3 Overview of Major Technical Development

2.3.1 Improvement of Running Speed (Fig. 6)
Since current collection devices account for a large percentage of wayside noise made in high speed running, we developed a current collection system with one pantograph per trainset where there were previously two pantographs per trainset. For the pantograph, we developed a new low-noise pantograph that has a “multi-segment slider” made up of many segments that can flexibly follow overhead contact lines by supporting each segment of the slider with springs. This development and factors such as lighter weight and higher tension of contact wires enables extremely stable current collection even in fast running.

To ensure safety when running when earthquakes strike, we conducted development for shortening the emergency braking distance and deviation prevention car guides that prevent cars from deviating greatly from the track even in derailment. And in order not to cause increased risk in an earthquake with greater speeds, we have improved the trainset braking force control that makes full use of adhesion of each car of the train as well as braking control in wheel slip or slide. We have also developed an unconventional braking method using equipment for increasing air resistance.

Fig. 6 Overview of Major Technical Development (Improvement of Running Speed)

In order to achieve stable high-speed running, we have developed many types of high-output compact and light main circuit systems with differing characteristics in their motor system and cooling system. We have also built an onboard information network and equipped trainsets with a car information control unit that transmits control commands and controls devices. Using that, we have been able to make full use of adhesion in the high-speed range for a method of controlling optimal torque and braking distribution based on the axle position in the trainset in case of wheel slip or slide. We have confirmed the effectiveness of that method that can secure accelerating force and braking force for the whole trainset.

2.3.2 Ensuring Safety and Reliability (Fig. 7)
In order to handle the increased load on bogies and their components at higher running speeds, we have designed bogies and axles based on data of test vehicles produced in the past and developed new types of basic brakes, axle bearings, drive devices, etc. We also developed a new monitoring system that can detect abnormality in bogie vibration, axle bearings and drive devices, etc. and developed new types of basic brakes, axle bearings, drive devices, etc. We also developed a new monitoring system that can detect abnormality in bogie vibration, axle bearings and drive devices, etc.

For wayside improvements, we compared and verified compared two types of long nose shapes and different nose lengths. For wayside improvements, we compared and verified compared two types of long nose shapes and different nose lengths. For wayside improvements, we compared and verified compared two types of long nose shapes and different nose lengths.

Fig. 7 Overview of Major Technical Development (Ensuring Safety and Reliability)

2.3.3 Consideration for the Environment (Fig. 8)
Noise control is an important issue for increasing Shinkansen speeds because it is particularly important in Japan to keep down noise along railway lines. The main measures for rolling stock are reduction of noise from pantograph frames as a countermeasure against aerodynamic noise from pantographs, single arm type low-noise pantographs, pantograph noise insulating panels, smooth covers between cars, smoother handles of the cab door, snowplow covers, plug-type doors, countermeasures against bogie cover aerodynamic noise, and development of noise absorptive structures for skirts of the underpart of the car body and the underfloor part. As for wayside spot measures, we have conducted technical development of a new noise barrier that has a higher diffracting attenuation effect by improving the upper part of the barrier.

As countermeasures against tunnel micro-pressure waves that increase as the running speed of the Shinkansen increases, we compared and verified compared two types of long nose shapes and different nose lengths. For wayside improvements, we developed a tunnel entrance hood with ducts and a light-panel tunnel entrance hood to reduce cost.
2.3.4 Improvement of Passenger Comfort (Fig. 9)

In order to reduce horizontal and vertical vibration in high-speed running, we made a complete review of the specifications and features of bogies and made many adjustments through running tests. Furthermore, we changed actuators of the active suspension system from air type to electromagnetic direct driven type and roller spring type to improve the response and control characteristics, reducing horizontal vibration.

For better ride comfort in curves, we introduced an air spring stroke type of car body tilting system with a simple structure. This enabled faster speed in curves while controlling excess centrifugal acceleration. And as a way to prevent car body vibration in tunnels caused by aerodynamic excitation in coupled operation, the anti-vibration device control method was improved on for better ride comfort.

2.4 Application of FASTECH Development Results to Trains in Commercial Operation

As a result of studying environmental measures and cost performance based on the aforementioned FASTECH360 test results, we set the commercial operating speed of series E5 and E6 rolling stock—successors to the series E2 and E3—at 320 km/h, the fastest in Japan.

Major items applied to series E5 Shinkansen rolling stock as a result of development in the FASTECH project are as follows (Fig. 10).

- **Environmental performance**
  - Long nose shape (nose length of 15 m) lead car
  - Bogie covers, smooth full covers between cars, low-noise pantographs
- **Improved running performance and ensuring reliability**
  - Main circuit devices, multi-segment slider pantographs, brake devices
- **Improvement of comfort**
  - Electronic full active suspension (all cars of the trainset)
  - Air spring stroke type of car body tilting system

While the initial target of 360 km/h commercial operation speed was not quite reached, we achieved rolling stock that met requirements for safety, reliability, and comfort at speeds 45 km/h faster than before. As so, we believe the project has been a major success.
3 Technical Development for Next-generation Shinkansen

3.1 Image of Shinkansen to Achieve
As mentioned in the introduction, it is our mission to make the Shinkansen attractive and comfortable so that it will be chosen by customers. In considering an image of the Shinkansen that will be a successor to the series E5 and E6, the keywords we work with are “safety/stability”, “amenity”, “efficiency”, “environmental performance”, and “intelligence” (Fig. 11).

Achieving safety/stability is the mission of a railway operator in order to allow customers to use it with peace of mind. As such, we aim for resilient railway systems that enable the status of rolling stock and wayside equipment to be identified in real time and that information to be shared and that are not easily affected by external factors. For amenity, we aim for increased convenience of arriving at destinations quicker due to speed increases as well as to provide functional services according to customer demands and a quality cabin space. For efficiency, we aim to reduce maintenance by monitoring and condition-based maintenance (CBM), to reduce costs by best matching equipment and rolling stock, and to streamline equipment. For environmental performance, we aim to maintain and improve the wayside environment in terms of noise and micro-pressure waves and to improve energy conservation performance. In order to achieve those goals, we believe that rolling stock needs to be made “intelligent” by utilizing IoT and AI.

Fig. 11 Major Characteristics of Next-generation Shinkansen

3.2 Issues in Speed Increases and Elemental Development
Arriving at the destination quicker is an important element in terms of customer service, and faster speeds will continue to be an issue to pursue. Through R&D in the FASTECH project, we have been able to narrow down issues in aiming for the 360 km/h speed range, but the hurdles to overcome are extremely high for all of those. Those issues cannot be overcome overnight, but we continue to make efforts in R&D based on experience up to now as we aim to make further progress. The following introduces some typical examples.

(1) An important issue brought up in increasing Shinkansen speeds is reducing wayside noise when trains run at high speed. The main sources of noise with the Shinkansen are pantographs and the area around bogies. In reduction of pantograph noise, we investigated through simulations elements causing noise, evaluated shapes to counter those in wind tunnel tests and the like, and investigated means of sound insulation and absorption; and we are proceeding with development of comprehensive sound reduction measures. As for aerodynamic noise from bogie components, we are working to identify sources of sound and investigating countermeasures against that. For aerodynamic noise generated with rotation of brake discs, a particular source of sound around the wheels, we are developing a disc cooling fin shape that reduces noise (Fig. 12).

Fig. 12 Wayside Noise Reduction Measures

(2) How to slow down and stop from high-speed running as quickly as possible is an important issue in ensuring safety when earthquakes strike. Currently, trains are only equipped with mechanical brakes (disc, caliper, and lining) that rely on adhesion between wheels and rails, but we are developing non-adhesive deceleration increasing systems to compliment in earthquakes adhesive braking insufficient at high-speed ranges and reduce braking distance. One of those is an “aerodynamic drag plate unit”, which is downsized and distributed equipment for increasing air resistance, nicknamed “cat ears” with FASTECH. Another is a “linear deceleration increasing device” that applies linear technology (Fig. 13).
(3) One characteristic of Shinkansen rolling stock operation by JR East is through service between Shinkansen and conventional line sections. Rolling stock for such through service must have high-speed running stability on Shinkansen sections and curve performance on small-radius curves on conventional lines. As maximum running speed on Shinkansen sections increases, it becomes more difficult to maintain performance in both areas. However, we are working to overcome that issue by optimizing bogie specifications such as longitudinal stiffness of primary suspension and yaw damper attenuation (Fig. 14).

![Fig. 14 Investigation of Performance of Rolling Stock for Through Service Between Shinkansen and Conventional Lines](image)

### 4 Conclusion

JR East announced its “medium-to-long-term vision for technological innovation” in November 2016. The concept of this vision is to bring about a revolution in mobility by actively utilizing IoT, big data, and AI. Achieving the next-generation Shinkansen we are working on will play a part in this revolution in mobility.

We would like to achieve intelligent Shinkansen rolling stock that utilizes IoT and AI technologies, which are seeing rapid technical advances, and create a Shinkansen that passengers can use safely, comfortably, and with peace of mind. We intend to make that a reality through technical development while performing trial and error in defining and achieving intelligent rolling stock.