20 Years of Railway Technical Research Institute (RTRI)

Kazuhiko Tezuka

The Railway Technical Research Institute (RTRI) assumed responsibility for the research and development (R&D) activities previously conducted by Japanese National Railways (JNR). It conducts R&D in a variety of fields, including structures, rolling stock, electrical power, signal communication, environment, energy, and human sciences. The institute has contributed to the development of the JR group of companies and railways in Japan in general by achieving success with a range of projects, including maglev, increasing the speed of shinkansen and conventional trains in harmony with the environment, strengthening ground equipment, reducing maintenance costs and taking measures to prevent accidents and natural disasters.

Introduction

RTRI was established in December 1986 with permission from the Minister of Transport just prior to the privatization and division of JNR. Consequently, it celebrated its 20th anniversary in December last year. I would like to review its 20-year history and introduce our Master Plan, the central focus of research initiatives, and some of the main results that the institute has achieved.

Changes In and Activities Conducted under Master Plan

RTRI was established as an organization to take over responsibilities for R&D that had been conducted by JNR. It began full-fledged R&D in April 1987, at exactly the same time the six JR passenger companies and JR Freight commenced operations. The institute has formulated a Master Plan approximately every 5 years since its establishment to set down fundamental policy regarding activities.

R&D Master Plan (March FY1988–89)

'Independence and autonomy' and 'an open research system' were designated as operational fundamentals to specify the direction of RTRI activities. 'Revitalization of conventional railways' and 'new style railways' were designated as the focus of R&D policy. Key designated projects included increasing the speed of the shinkansen to 300 km/h, environmental measures, maglev, intelligent railways and next-generation operational control systems.

Medium-term Master Plan (FY1990–94)

In June 1990, the Master Plan for development of technology for superconducting magnetic levitation railways and the plan to construct the Yamanashi Test Line both received approval from the Minister of Transport. The Medium-term Master Plan was thus formulated in March 1991 to reflect this. In this plan, maglev and increasing the speed of shinkansen and conventional trains in harmony with the environment (ATLAS plan and NEXT 250 plan) were designated as the focus of R&D initiatives. In November 1990, the new rolling stock test unit was completed and an integrated office automation system was begun; in FY1992, the high-speed rolling-stock brake test unit was completed.

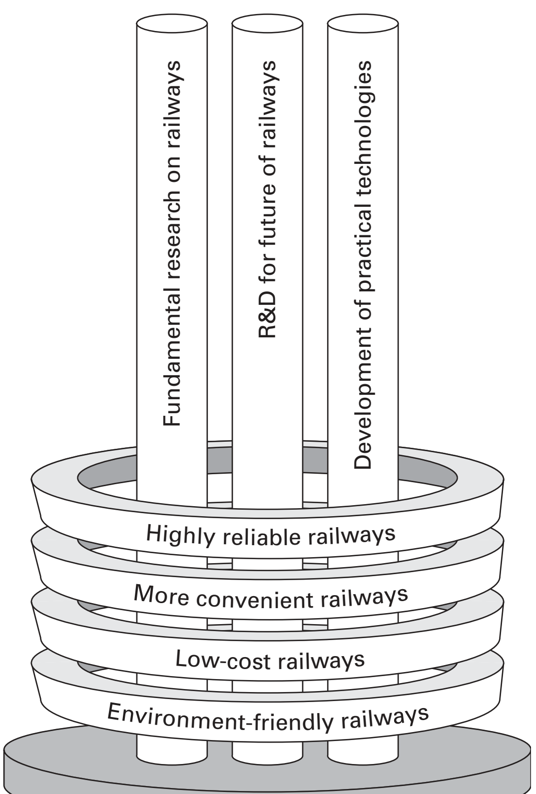
Revised Medium-term Master Plan (FY1995–99)

The Medium-term Master Plan was revised in March 1995 to take into account the extension in the period of the Yamanashi Test Line Experiment Plan to FY1999. As well as revising the plan for development of the maglev, the details of the SUCCESS 21 plan (the findings of a transport technology committee) and changes in the technological development needs of the JR group of companies were incorporated and the project on conventional railways was revised. The principal matters covered in this plan were the importance of environmental measures, improvement of maintenance, including that of rolling stock, and enhancement of transportation in the Tokyo metropolitan area. Earthquake measures were also treated in the same way as a project, following the earthquake in Southern Hyogo Prefecture in January 1995. At the end of FY1995, a large-scale, low-noise wind tunnel was completed in Maibara and in July 1996, the Railway Technology Promotion Center (RTPC) was established within RTRI. The Yamanashi Maglev Test Center opened the same month, and test runs began in April 1997.

Master Plan—RESEARCH 21 (FY2000–04)

The R&D objectives of this plan were designated as 'reliability, safety and stability,' 'low cost,' 'speed, convenience and comfort' and 'harmony with the environment.' The central pillars of the plan were R&D for the future of railways (issues for future), practical technological development, fundamental railway R&D of a maglev. For future issues, 12 problems were selected and two added later for a total of 14 in an attempt to look forward to railway technology that will be created and come into practical use within a period of a few years to a few decades.

Figure 1 Objectives and Focus of R&D under RESEARCH 2005



Master Plan—RESEARCH 2005 (FY2005–09)

With the maglev R&D project in March 2005, the Superconductivity Magnetic Levitation Railway Feasible Technology Assessment Committee of the Ministry of Land, Infrastructure and Transport reached the verdict that the fundamental technology for commercialization had been realized. In light of this, it is understood that the previous stage of developing technology for the commercialization of maglev conducted by RTRI was concluded in FY2004. Based on this realization, exactly the same four R&D objectives as in the previous Master Plan were inherited for RESEARCH 2005 formulated in November 2004. Issues for the future, practical technological development and fundamental research were selected as the focus of R&D (Fig. 1). For linear motor-related technology and know-how, the central theme of R&D was application to conventional railways.

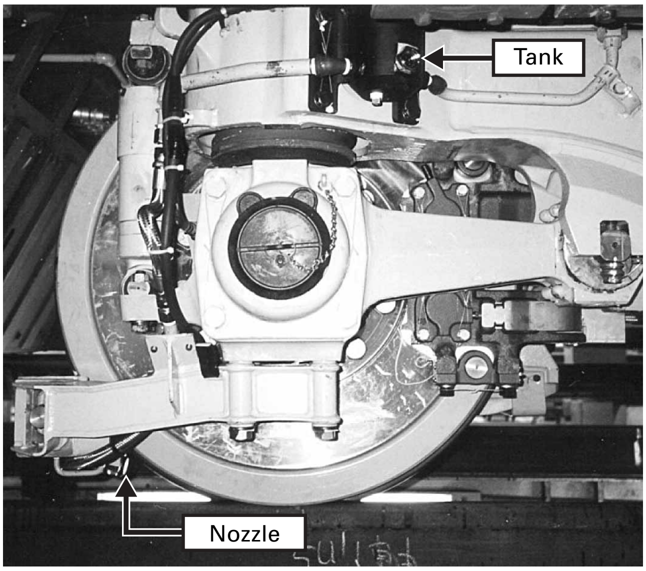
Main R&D Results

RTRI conducts R&D in a variety of fields, including structures, track, rolling stock, electrical power signalling, disaster prevention, the environment, materials, and human sciences. As well as helping to deepen knowledge about fundamental matters, the results have been put to practical use in many fields. I would like to introduce several such topics.

In developing a maglev, we have many research findings related to cars and superconductivity systems.

Superconducting maglev

RTRI continued to conduct levitated test runs on the Miyazaki Test Line after acquiring the line from JNR. A speed of 431 km/h was achieved with the MLU002N test vehicle in 1994. Test runs have also been conducted at the Yamanashi Test Line, which was jointly built by JR Central and Japan Railway Construction Public Corporation (now Japan Railway Construction, Transport and Technology Agency). The world speed record of 581 km/h was achieved at this site with the MLX01 test vehicle in December 2003. A considerable amount of research has been conducted on superconducting magnets, rolling stock, ground coils, guide rails and power-supply systems. In FY2005, it was determined that the fundamental technology for commercialization of a superconducting magnetic levitated transport system had been established.



Cerajet has been used on many carriages. Ceramic particles are sprayed at high speed between the wheels and rail to prevent wheel slide and slip.

Increasing speed of shinkansen and environmental measures

Following the establishment of the JR, efforts began again to increase the speed of shinkansen and conventional trains because it had been neglected at the end of the JNR era.

To prevent increased ground vibration along the line caused by higher speeds, it is necessary to make rolling stock lighter. Bolsterless undercarriages were developed for shinkansen trains designed to travel at 300 km/h for this very reason. They are approximately 30% lighter than conventional undercarriages and are used for Series 300 shinkansen trains. The use of Ceramix is also widespread. With this system, aluminium oxide or other ceramic particles are sprayed at high speed between the wheel and rail of the train to prevent sliding when it is raining. Further, 40m-versine long-wave track irregularity control is used, which is suitable for travel at high speeds. Semi-automatic suspension allows computer control of the dampers between the body and the undercarriage. Yaw dampers have also been developed to couple carriages. All these measures make a shinkansen ride significantly more comfortable.

To ensure a stable supply of electricity from the pantograph to high-speed trains, a trolley wire with high tensile strength relative to its mass is required. RTRI developed the CS and PHS trolley wires for this purpose.

With high-speed trains, aerodynamic noise contributes significantly to the track noise. We used a wind tunnel and a simulator to clarify this noise-generating mechanism. In addition to developing a method to predict the noise, we established the basic design concept for low-noise pantographs, which are essential for increasing speed.

Various methods are effective for reducing ground vibration along the train line, including making rolling stock lighter, performing work to counteract or block the vibration and reducing the resilience of the track. Type-D resilient-sleeper direct coupling and various types of work to block the vibrations are used commercially. We have also developed a method of quantitatively evaluating such measures using a model of ground vibration, plans for blocking vibration, and a method of calculating the effect of work to counteract vibration so designs can be optimized.

We have also performed experiments and analysis to understand the mechanism behind the emitted microbarometric waves, producing a large amount of noise at the portals of long tunnels when a high-speed train enters on slab tracks. The results have been used to propose solutions for the optimum positioning of sound baffles and the optimum nose shape of the lead car.

Increasing speed of conventional trains

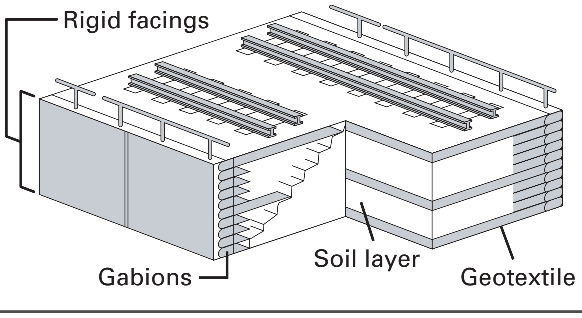
To reduce journey times for conventional trains, on many lines it is usually more effective to increase the speed on curves rather than increase the maximum speed of the train. Higher speeds can be achieved for tilting trains if a pendulum cylinder is used for control to tilt the train body to the appropriate angle on curves. We developed a tilting train with a control mechanism that is used by all the JR passenger companies, starting with the Series 2000 limited-express carriages for JR Shikoku. In addition, some trains operated by JR Hokkaido use an RTRI-designed undercarriage with wheel steering that reduces the lateral force of wheels on the rail on curves.

RTRI has developed prototypes of a 100-kW fuel-cell system and a 35-MPa high-pressure hydrogen tank system and is currently conducting test runs to evaluate the performance of these systems.

Ground equipment

Railways require a variety of large and elongated fixtures, including elevated sections and normal bridges, tunnels, track, overhead catenary lines and signals. Conducting R&D into developing new systems to enhance the functions of such equipment and reducing construction and maintenance costs is an important management issue for railway companies.

Figure 2 Summary of RRR Construction Method



Since its establishment, RTRI has been commissioned by the Japanese government to publish design standards for 11 types of railway structures. Based on these standards, we have formulated 14 design programmes that are used by many structure designers. The RRR (reinforced railroad/road with rigid facing) construction method is a new method that is used throughout Japan (Fig. 2), including on roads and residential land. This method offers many advantages, including reducing the area required by constructing permanent vertical retaining walls against which soil layers are placed. The radish anchor construction method is used to reinforce and strengthen embankments against a wide but small anchor. This method is used for a variety of objectives, such as excavation and reinforcing slopes.

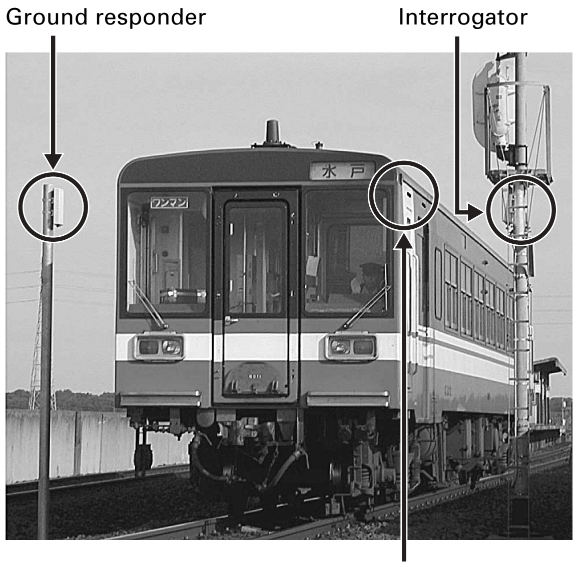
We have developed a range of maintenance systems, including IMPACT, a nondestructive method of inspecting the state of bridge columns used by many railway companies. We have also developed systems to evaluate the soundness of concrete structures and steel railway bridges and the condition of tunnels.

Moreover, we have developed a ladder track using a longitudinal sleeper in the shape of a ladder comprising vertical beams made from pre-stressed concrete and a horizontal linking material made from steel. This track is beginning to be used in various locations. A track maintenance database we developed called MICROLABOCS is also being used by many companies. We have also proposed a method of calculating the approximate shape of a track using signal processing from 10 m-versine track irregularity waveform, a method of grinding rails to prevent fatigue cracks called 'shelling', and conditions for extending the scope of application of long rails to curves, points and crossings.

Maintenance of overhead catenary, the large structure above the track, is an important issue. We have developed a trolley-wire wear tester that uses a low-pressure sodium lamp, which helps increase efficiency, as well as equipment using eddy current to measure the corrosion and deterioration of electrical wires.

In the field of signals and train control, a digital ATC system has been put to commercial use. It provides efficient control while maintaining safety through stepped-brake control. We have proposed a train control system called CARAT that is about to be put into commercial use by JR East. It is a moving block system that continuously detects the position of the train by radio without using track circuit equipment. The block system called COMBAT for less heavily used track sections offers outstanding safety and reliability at low cost. Instead of track circuits, it uses a balise radio detector to detect trains entering or passing through an area where a train has already been detected. COMBAT is nearing commercialization and is expected to produce labour-saving benefits (Fig. 3).

Figure 3 COMBAT Block System for Quiet Track Sections



Others

This short article has only briefly mentioned a very small selection of the R&D results achieved by RTRI. The institute conducts a wide range of R&D activities related to railways at various stages from understanding basic phenomena to commercialization. Areas include measures to prevent derailments, collisions, railway-crossing accidents and accidents caused by railway staff; measures to prevent damage from natural disasters such as earthquakes, strong winds and rain; clean-energy cars that use fuel cells and lithium secondary batteries; non-contact cards, providing information to the mobility impaired, increasing convenience by predicting the movement of passengers in stations, and fundamental research into new materials and the causes of derailments and other accidents. Readers who wish to find out more about RTRI should consult RRR, our journal published each month. It explains the R&D activities of RTRI and related technologies in an easy to understand way.

Conclusion

Over half the researchers now at RTRI were hired soon after the institute was established. This means that the growth period using equipment, human resources and other assets acquired from the JNR days is coming to end. Conditions in railway research are also changing considerably. JR East and JR Central have established their own directly managed research institutes, and public research organizations and universities have become independent organizations.

In such an environment, we look forward to the future of railways and continue striving to contribute to society as a technical organization through our high-quality railway research.

Kazuhiko Tezuka

Mr Kazuhiko Tezuka is Director of the RTRI Planning Division. After post-graduate studies in mechanical engineering at Keio University, he joined JNR in 1976. He was Laboratory Head at the RTRI Vehicle Dynamic Laboratory, and Director of the Vehicle Structure Technology Division before assuming his present post in 2006.

Chronology of Main RTRI Events

Year	Month	Date	Events
1986	Dec	10	Minister of Transport approves establishment of Railway Technical Research Institute (RTRI)
1987	Apr	1	RTRI acquires R&D arm of Japanese National Railways (JNR) at privatization and division
			Full-scale operations start
			Masaru Ibuka becomes first chairman and Masanori Ozeki first president
			Office system starts operation
	Apr	30	First R&D Coordinating Committee
	Jul	15	RTRI designated as agency by Ministry of Transport for inspection of completed work on rail facilities on behalf of national government
	Sep	24	Inspection by Minister of Transport Ryutaro Hashimoto
	Oct	15	First RTRI monthly presentation meeting
		23	Minister of Transport Ryutaro Hashimoto rides MLU002 at Miyazaki Maglev Test Track
	Nov	9	Seminar on Current State and Future of High-Speed Transport Systems with Magnetic Levitation held by RTRI and Nikkei Inc.
	Dec	10	First anniversary of RTRI
			RTRI flag unveiled
			Special lecture by Sony Chairman Akio Morita, on Japan in the World
		14	Minister of Transport Shintaro Ishihara rides MLU002 at Miyazaki Maglev Test Track
1988	Feb	5	Final report by Amarube Accident Technical Investigation Commission
	Sep	19	Inspection by Minister of Transport Shintaro Ishihara
		27	RTRI Seminar—Deep-Level Underground Railways
	Nov	9	First RTRI public lecture—Improving the Railway System (Nikkan Kogyo Hall)
	Dec	1	SX-1E supercomputer starts operation
		1–10	First RTRI Idea Competition
1989	Jul	17	Minister of Transport Shinjiro Yamamura rides MLU002 at Miyazaki Maglev Test Track
	Sep	20	Minister of Transport Takami Eto rides MLU002 at Miyazaki Maglev Test Track
1990	Jun	25	Minister of Transport approves fundamental plan for technical development of superconducting magnetic levitation railway and construction plan for Yamanashi Maglev Test Line
	Nov	15	New rolling stock test plant opens
1991	Mar	31	Human science Test Plant E starts
	Oct	3	Fire destroys MLU002 at Miyazaki Maglev Test Track
	Dec	7	Shinkansen test car (Series 951) transferred to Kokubunji
1992	Mar	27	Yoshinosuke Yasoshima becomes second chairman
	May	11	RTRI work start and finish times recorded using non-contact IC card
	Dec	2	Production of MLU002N test car for Miyazaki Maglev Test Track completed
		15	Collaborative research agreement with China Academy of Railway Sciences
1993	Jan	31	Brake test plant completed
	Nov	1	Inspection by Minister of Transport Shigeru Ito
1994	Nov	4	Web site goes online
		13	Research cooperation agreement with International Union of Railways (UIC)
		14–16	World Congress on Railway Research WCRR'94 in Paris, France
1995	Jan	17	Kobe earthquake restoration support headquarters established
		26	MLU002N records speed of 411 km/h on manned run at Miyazaki Maglev Test Track
	Jul	16	Yamanashi Maglev Test Line Test car (MLX01) delivered
		27	Agreement reached with Association of American Railroads (AAR) on use of Pueblo test line in Colorado
	Sep	21	Inspection by Minister of Transport Takeo Hiranuma
	Nov	6	Windows comprehensive office system THEOA begins operation
		13	Research cooperation agreement entered into with SNCF (French National Railways)
1996	Jun	5	Ceremony held to commemorate completion of large-scale low-noise wind tunnel
	Jul	1	Yamanashi Maglev Test Center opens
			Railway Technology Promotion Center established
	Oct	9	Running tests at Miyazaki Maglev Test Track end after 19 years
	Dec	10	Ceremony commemorates 10th anniversary of RTRI
1997	Mar	21	First railway design engineer examination
	Apr	1	Hiroumi Soejima becomes second president
		3	Running tests start at Yamanashi Maglev Test Line
	May	6	Gauge Change Train (GCT) project starts
		12	Ladder track tests start at RTRI
	Jun	1	RTRI joins UIC
	Oct	22	10th RTRI Lecture—Taking on the Challenge of Pushing the Yamanashi Maglev Toward 550 km/h (Yamaha Hall)
		25–26	Yamanashi Maglev Test Line Test car (MLX02) delivered

1998	Apr	12–15	MAGLEV'98 in Yamanashi
	May	17	Minister of Transport Takao Fujii rides MLX01 at Yamanashi Maglev Test Line
	Oct	10	Shinkansen high-speed test cars (WIN350, STAR21) displayed to public at Wind Tunnel Technical Center
	Nov	2	GCT delivered to Kunitachi Institute
		18	Yoshiji Matsumoto becomes third chairman
1999	Jan	22–31	GCT running test on San'in Line
	Apr	12	GCT tests start at Pueblo test line in USA.
	Oct	19–23	RTRI holds WCRR'99 at Kunitachi Institute
		18	Minister of Transport Toshihiro Nikai rides MLX01 at Yamanashi Maglev Test Line
2000	Feb	9	Shima Library established following gift of book collection from Hideo Shima, former JNR Chief Engineer
	Mar	9	Committee for Evaluation of Technological Feasibility of Superconducting Magnetic Levitation concludes that maglev ultra high-speed mass transportation system practical
	Jun	28	Railway design engineer examination receives accreditation from Minister of Transport
	Jul	24	Minister of Transport Hajime Morita rides Yamanashi Maglev Test Line
	Aug	26	Total of 100,000 km of test runs on Yamanashi Maglev Test Line
	Sep	14	Minister of Transport Hajime Morita visits RTRI for inspection
	Oct	16	Chinese Premier Zhu Rongji rides MLX01 at Yamanashi Maglev Test Line
2001	Jan	26	Prince Akishino and Princess Kiko ride MLX01 at Yamanashi Maglev Test Line, first members of Imperial Family to do so
		30	All GCT tests finished at Pueblo test line in USA. and GCT removed on 6 February
			Total distance: 591,949 km, total gauge changes: 2,084
	Apr	12	RTRI President Hiroumi Soejima visits USA. and speaks with Secretary of Transportation Norman Y. Mineta
	Jun	7	First China–Korea–Japan Railway Research Technical Meeting held at Korea Railroad Research Institute (KRRI)
	Aug	27	Test runs start on RTRI test line to determine cause of wheel-climb derailment
2002	Mar	19	Improvement work on current collection testing setup finished
	Jul	25	Test runs on Yamanashi Maglev Test Line start with new leading car and new intermediate car
		26	Shinkansen high-speed test car (300X) stored at wind tunnel technical center
	Aug	8	Technology Research Association of Gauge Changing Train established and RTRI takes part as member
	Oct	9–11	Second China–Korea–Japan Railway Research Technical Meeting at Kunitachi Institute
	Dec	11–12	SNCF–RTRI Joint Research Seminar at Kunitachi Institute
2003	Jan	30	High-temperature superconducting magnet generates world's strongest magnetic field—17 teslas (achievement published in *Nature*)
	Mar	4	On-board comfort simulator completed
		25	Rail Advisor program starts at Railway Technology Promotion Center
	Jul	26	Total of 300,000 km of test runs on Yamanashi Maglev Test Line with 50,000 people riding line
	Oct	7	2,876 km (89 round trips) of test runs on Yamanashi Maglev Test Line in 1 day
	Dec	2	Speed of 581 km/h attained on Yamanashi Maglev Test Line
2004	Jan	22	Wear test machine for current collection materials for high-speed railways completed
	Feb	18	World first electric train bogie successfully driven by fuel cell in test
	Mar	18	Super high-speed train model launching equipment completed
	Jun	21–24	China–Korea–Japan Railway Research Technical Meeting at Korea Railroad Research Institute (KRRI)
	Oct	14	Railway Technology Promotion Center wins Third Japan Railway Awards' Special Award
	Nov	16	Two trains passing each other record relative velocity of 1,026 km/h on Yamanashi Maglev Test Line
	Nov	22–26	Japan–France Joint Research Seminar in Paris, France
2005	Jan	29	Crown Prince Naruhito rides Yamanashi Maglev Test Line
	Mar	11	Committee for Evaluation of the Technological Feasibility of Superconducting Magnetic Levitation comments that key technology established for practical application
	Apr	1	Katsuji Akita becomes third president
	May	19	First LRT Technology Evaluation Meeting at Tokyo Yayoi Kaikan
		25	Inspection by Minister of Land, Infrastructure and Transport Kazuo Kitagawa
	Jun	21–23	5th China–Korea–Japan Railway Research Technical Meeting at Kunitachi Institute
		22	Development of energy-saving battery-driven light-rail vehicle using regenerative energy selected as New Energy and Industrial Technology Development Organization (NEDO) grant project
	Sep	21	Mc3 leading car for Yamanashi Maglev Test Line delivered to Kunitachi Institute
	Oct	25–26	10th SNCF–RTRI Joint Research Seminar at Kunitachi Institute
	Nov	2	First test train unveiled at RTRI
2006	Mar	15	Total of 500,000 km of test runs reached on Yamanashi Maglev Test Line
	Jun	29	Minister of Land, Infrastructure and Transport Kazuo Kitagawa rides MLX01 at Yamanashi Maglev Test Line
	Jul	1	10th anniversary of establishment of Railway Technology Promotion Center
			10th anniversary of opening of Yamanashi Maglev Test Line
	Aug	3	Ceremony to commemorate 10th anniversary of opening of Wind Tunnel Technical Center
	Sep	7–8	Fuel-cell car unveiled at RTRI forum
	Dec	10	20th anniversary of RTRI
	Dec	13	Ceremony to commemorate 20th anniversary of RTRI