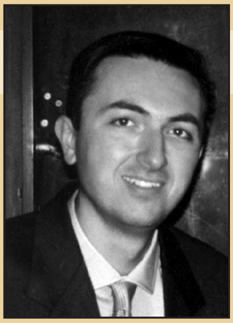

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Creating a Digital-Vehicle Proving Ground

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This installment presents the state of the art of ITS research in China, particularly the facilities and the proving ground for testing automated vehicles. The 2003 IEEE ITS Conference will be held in China; I'm sure this could be an interesting opportunity to visit these facilities. Please check www.ieeeitsc.org for updates.

If you have any comment on this department, feel free to contact me. I also seek contributions on the current status of ITS projects worldwide as well as ideas on and trends in future transportation systems. Contact me at broggi@ce.unipr.it; www.ce.unipr.it/broggi.

—Alberto Broggi

The Chinese automotive industry has become an important component of the worldwide automotive industry. According to the leading Chinese newspaper, *People's Daily* (25 Dec. 2002), the Chinese automotive industry has established more than 600 joint ventures and introduced 1,000 foreign technical inventions over the last 20 years. The total foreign investment has exceeded US$20 billion, more than 40 percent of the total Chinese automotive capital. The 2001 output reached 2.34 million vehicles, up from 0.71 million in 1991. This is a 3.3-fold increase and a 15 percent average annual increase, compared to the 1.5 percent annual increase worldwide in the same period. The 2002 output was 3.25 million vehicles.

The driving force for the Chinese automotive industry is passenger cars, whose production increased from 81,000 in 1991 to 700,000 in 2001, a 8.7-fold increase and a 24 percent annual increase. The National Information Center estimates that in 2003 the demand for passenger cars in China will be 1.5 million: 1.435 million domestic cars, an increase of 26.4 percent, and 90,000 imports (*International Finance News*, 17 Dec. 2002). The Chinese automotive industry has a 5 percent share of the worldwide automobile market; its share should reach 20 percent by 2020, assuming a 5 percent annual increase and a total output of 10 million vehicles. Figure 1 shows China's automobile output from 1990 to 2002.

The Chinese automotive industry's rapid growth demands an increased, enhanced effort in R&D in vehicular technology, reliability, quality, safety, human comfort, and environmental impact. In 1999, China created its National Center of Intelligent Transportation Systems Engineering and Technology (the ITSC) and established the National Field Testing Complex (NFTC), a state-of-art, comprehensive facility in Tong County, Beijing. One major task for the ITSC is R&D in intelligent-vehicle technology to enhance safety, reliability, and performance. The Complex Systems and Intelligence Science Lab at the Institute of Automation, Chinese Academy of Sciences, has started a similar initiative. Since the early 1990s, the University of Arizona's ATLAS (Advanced Traffic and Logistics Algorithms and Systems) and PARCS (Program for Research for Advanced Systems) research centers have also made significant progress in ITS, particularly in vehicle technology, as demonstrated by the VISTA (Vehicles with Intelligent Systems for Transport Automation) and digital-highway projects.[1,2] To combine their strengths, in 2002 the ITSC, the Chinese Academy of Sciences, and the University of Arizona agreed to conduct joint research on a digital automobile proving ground (DAPG) for automated-vehicle driving tests based on their Beijing and Tucson facilities. Here we describe this international collaboration's status and progress.

Field-testing a complex DAPG

Figure 2 is a bird's-eye view of the NFTC. More than 400 million yuan (approximately US$60M) has been invested in this facility for design and testing equipment. It serves mainly as a proving ground for R&D prototype

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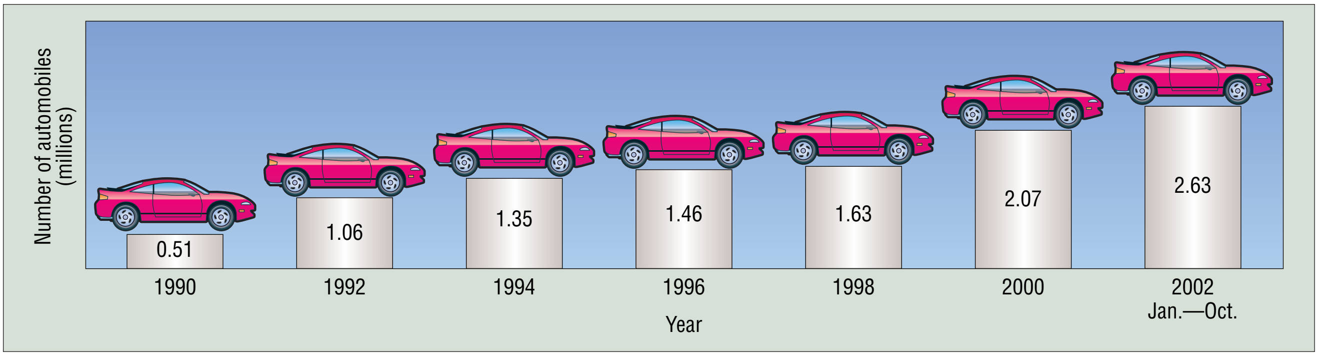

Figure 1. Automobile output in China from 1990 to 2002. (information source: Chinese Association of Automobile Manufacturers)

testing in ITS technology and an evaluation and certification center for commercial transportation and vehicle products. The international collaborators will use this complex to build a highly automated DAPG that provides test, engineering, and simulation services to a broad range of vehicle developers, manufacturers, and users, and government agencies. The first phase (2002–2005) will set up a proof-of-concept system at the NFTC. The system has these main purposes:

- Achieve reliable, qualitative, and repeatable testing results by eliminating variability due to human operations and reducing other varying factors.
- Implement fast, flexible, anytime, all-weather, and all-condition testing.
- Release human drivers from dull and hazardous vehicle-testing tasks.

Figure 3 presents the DAPG layout. The DAPG's completion will involve these key issues and technologies:

- Offline and real-time digital geographical information systems
- High-precision differential GPS
- A surface bar code calibration system
- An in-vehicle navigation system
- A vehicle-testing robot
- Data acquisition
- Wireless communication
- A control and command center
- Task-generating, planning, scheduling, and safety assurance systems

The communication and control & command centers

The field-testing complex is about 70 miles from the research facilities at the Chinese Academy of Sciences and the Research Institute of Highway. The Communication Center (CC—see Figure 4a) provides wireless communication capabilities to those remote facilities and the local testing vehicles at the DAPG. The Control & Command Center (CCC—see Figure 4b) implements and monitors vehicle-testing task planning, generation, scheduling, and execution.

A wireless (based on IEEE 802.11b) LAN that covers the testing area connects the field vehicles and surface equipment to the CC network via a network address translation

Figure 2. A bird's-eye view of the National Field Testing Complex.

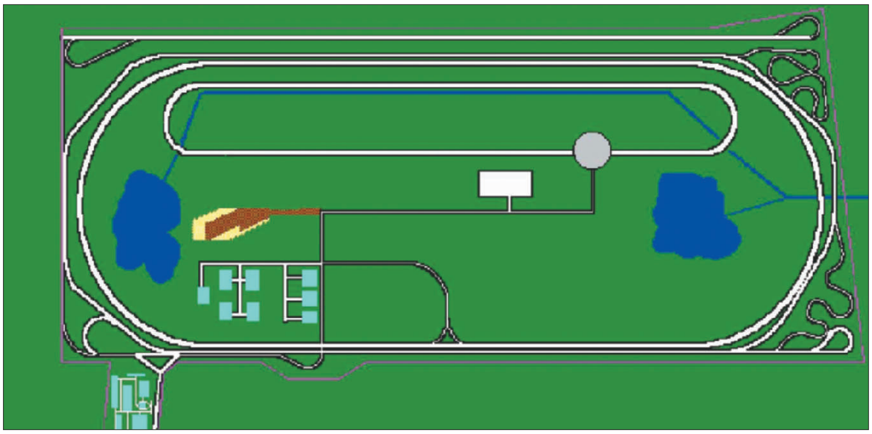

Figure 3. The layout of the digital automobile proving ground.

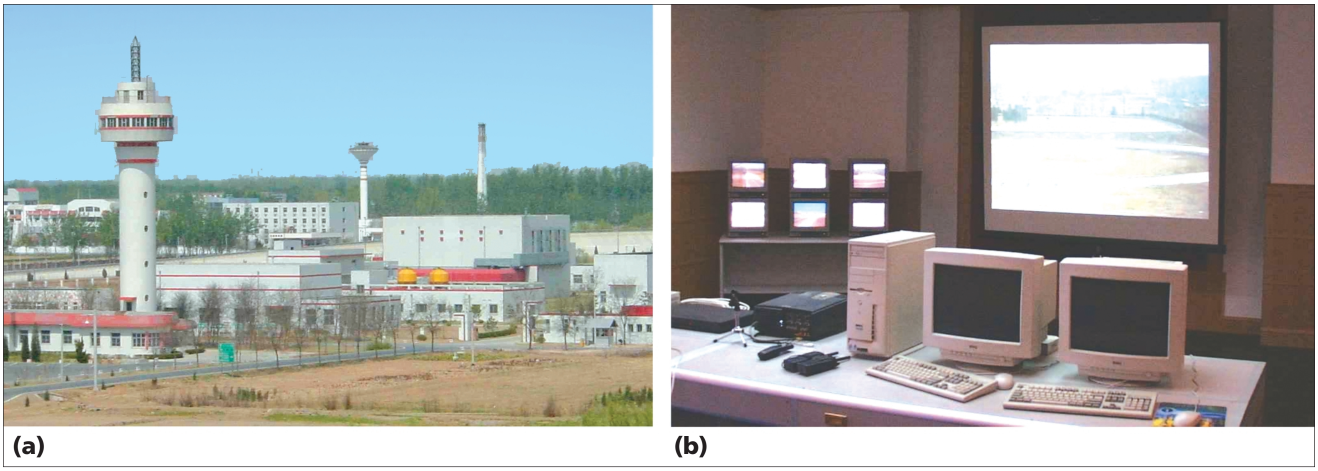

Figure 4. The DAPG's (a) Communication Center and (b) Control & Command Center.

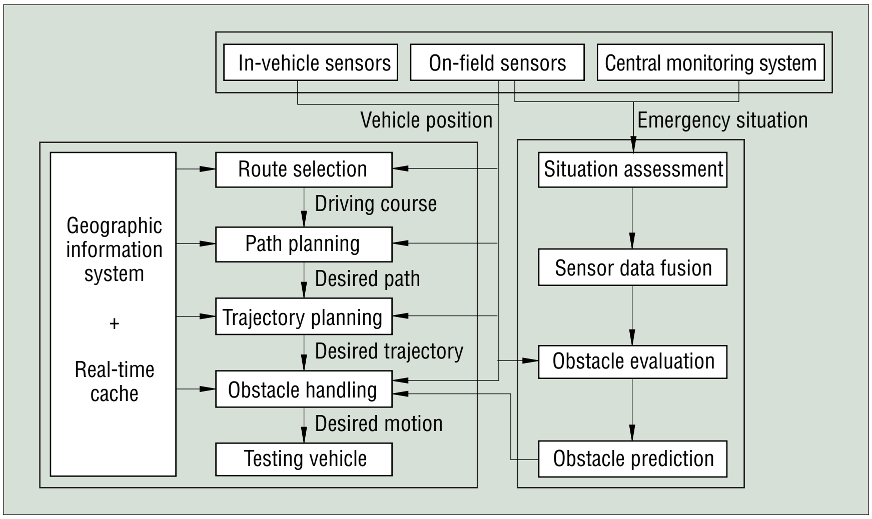

Figure 5. The DAPG system architecture.

box that keeps the set of local IP addresses invisible from outside the LAN. Currently, a set of laptops and computers serves as the gateway to link field vehicles, vision systems, and surface equipment to the CC network. Embedded communication capacity will be added later. For real-time management and operation, the DAPG uses a simple protocol to send and receive control and feedback information between the CCC and fixed and moving equipment in the field.

A system architecture for testing automated vehicles

Figure 5 shows the DAPG system architecture. The CCC uses a bar-code-based surface-coordinate system, magnetic nails, differential GPS, and in-vehicle navigation systems to track the vehicles on the DAPG. As we mentioned before, it also provides communication and control information to and among them. Each vehicle has a unique wireless ID. The CCC instructs and monitors each vehicle's movement for various driving tests. Each vehicle is considered an autonomous agent, equipped with various in-vehicle sensors and a driving-test robot, and communicating with the CCC and various surface sensors. The driving-test robot collects information from both the in-vehicle and surface sensors and decides its driving actions on the basis of its testing task under the CCC's guidance and supervision.[3]

The generation of testing tasks can be interactive or passive. In interactive generation, the CCC generates the task under operator instruction. In passive generation, the CCC chooses a preprogrammed task according to a task schedule. Normally, routine, repetitive tests will use passive generation.

The testing tasks fall into two groups. The first comprises standard driving tests:

- Tests for steering input, steering effort, lane changes, steady-state cornering, and other related vehicle dynamics, normally involving short distances on good-condition roads
- Vehicle durability tests on special roads and surfaces, normally involving long distances on poor-condition roads
- Traction-control tests that evaluate and optimize tire and suspension performance over a range of conditions

The second comprises special driving tests:

- An accelerated vehicle corrosion test, which occurs mainly in a special chamber
- Low-friction tests for antilock braking systems, which are mainly for global brake certification and are in conjunction with the traction control test and an all-wheel-driving test

For each test, special driving trajectory and robot control sequences are planned and produced.

Seven projects on wireless communication, robotic driving, in-vehicle sensory fusion, on-field calibration, trajectory generation, test-task planning, and system control and monitoring have been scheduled for the DAPG. The first application to assess DAPG's effectiveness will be the accelerated testing of a special tire design's driving performance. ■

Acknowledgments

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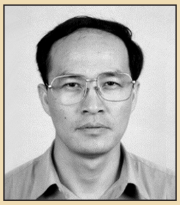

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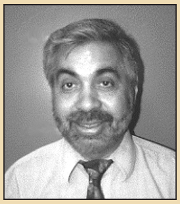

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