# Research and Development Activities of Hitachi's Overseas Laboratories

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*OVERVIEW: Following the growth of production and product development overseas, the expansion of overseas R&D operations for supporting regional business operations is continuing. Moreover, the so-called "off-shoring" of R&D to places with huge pools of human resources (such as China and India) in search of improved cost performance has become more active in recent years. In the meantime, for the sake of developing cutting-edge technologies, collaborative research between the world's top class research institutes is all the rage. Since 1989, Hitachi has been engaged in overseas R&D that makes best use of regional strong points. For example, in the USA, this R&D has been centered on supporting business (such as development of automotive technologies), and in Europe, in collaboration with the University of Cambridge, it has targeted cutting-edge devices. Moreover, research activities have been progressing in the economically booming China since 2000, and more recently in South East Asia, and a global R&D network is being expanded through collaborative efforts between these research centers and Hitachi's research centers throughout Japan.*

## INTRODUCTION

WITH over 400 group companies presently located outside of Japan, Hitachi has more than 110,000 oversea employees working at these companies. The globalization of corporate activities has become more active with each passing year. Similarly, in the research field as well, from the end of the 1980s up till the present, globalization has been hastily pursued.

This short article takes up representative cases of R&D (research and development) being performed at Hitachi's overseas R&D centers. In this article, the basic ideology and background concerning the R&D activities at Hitachi's overseas research centers are presented.

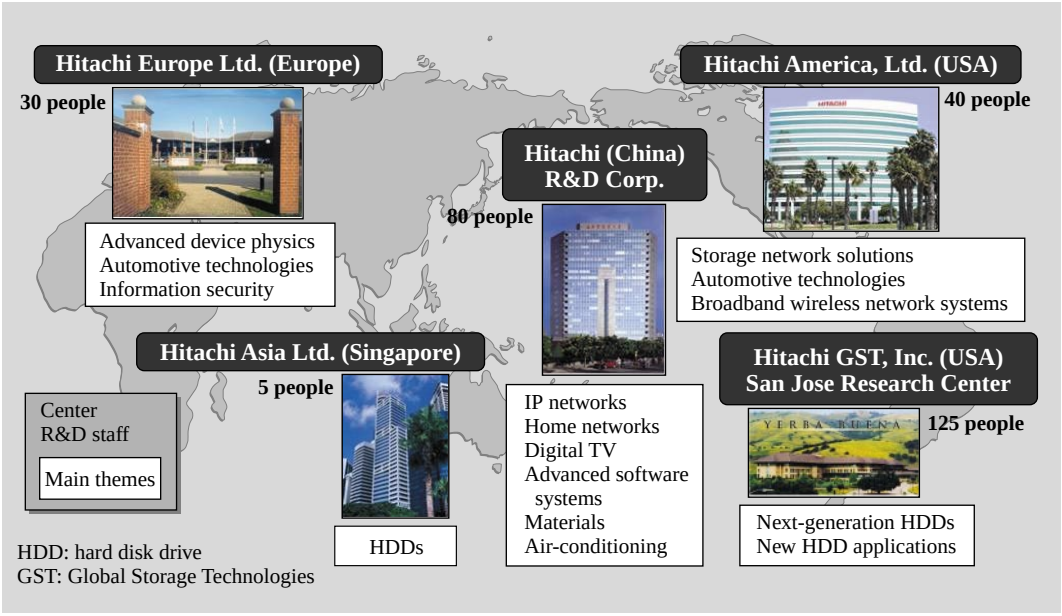


*Fig. 1—Overseas R&D Organization. Hitachi's R&D centers in the USA, Europe, China, and South East Asia and their main research themes are shown.*

## BACKGROUND TO OVERSEAS EXPANSION OF HITACHI'S R&D LABORATORIES

As the context of establishing overseas R&D centers, the advantages listed below are generally considered:

(1) On-the-spot business support such as shortening time periods for "product localization" in overseas markets

(2) Cutting-edge technical development by academic collaboration with influential universities and research establishments overseas

(3) Utilization of top-flight human resources overseas

(4) Reduction of R&D costs through "off-shore" R&D

Aiming at supporting global business expansion and new product and business creation in the global marketplace, Hitachi established R&D centers in the USA and Europe in 1989.

In the USA, R&D on on-the-spot business support aimed at cutting-edge markets and customers is mainly being pushed forward. Up till now, development of system LSIs for mobile equipment at our research laboratory in Silicon Valley, development of semiconductor devices for handling multimedia at our research laboratory in Princeton, and development of electronic and mechanical components of motor cars at our Detroit research center was performed and many of the achievements of this R&D have reached the market as commercial products. In recent times, in line with the strengthening of car-related businesses, the Detroit center is being beefed up. Furthermore, aiming at the progressing network era, the research framework regarding SAN (storage area network) solutions and cutting-edge wireless technologies is being enhanced.

In Europe, through collaborative research with world-class research organizations, we are pursuing advanced research in cutting-edge fields as part of our commitment to European Union projects while striving to contribute to expanding our European business. As for our industry-academia cooperation with the University of Cambridge in the UK, Hitachi Cambridge Laboratory (HCL) was established in the premises of the Cavendish Laboratory (which has produced over 30 Nobel Prize winners in the field of physics in the past), and collaborative research through unified efforts with the university's researchers is continuing. In October 2005, new research centers focused on automotive-related fields were established in Munich and Paris, thereby strengthening research for supporting our business in Europe.

In the meantime, in China, the country's excellent human resources are utilized fully, and to perform R&D aimed at the continually expanding Chinese market, a research center was set up at Hitachi (China) Ltd. in 2000. Split-off independently in April 2005 as the first specialized company within Hitachi for R&D, this research center became Hitachi (China) Research & Development Corporation. This research company is aiming to become the R&D platform for all Hitachi Group companies breaking into the Chinese market.

*Fig. 2—Cambridge University Cavendish Laboratory.*
*Over the years, the Cavendish Laboratory of the University of Cambridge has turned out many Nobel Prize winners in the field of physics. Within that laboratory, Hitachi's Cambridge Laboratory is pursuing joint research on fields (such as spintronics and quantum information processing) concerned with cutting-edge devices.*

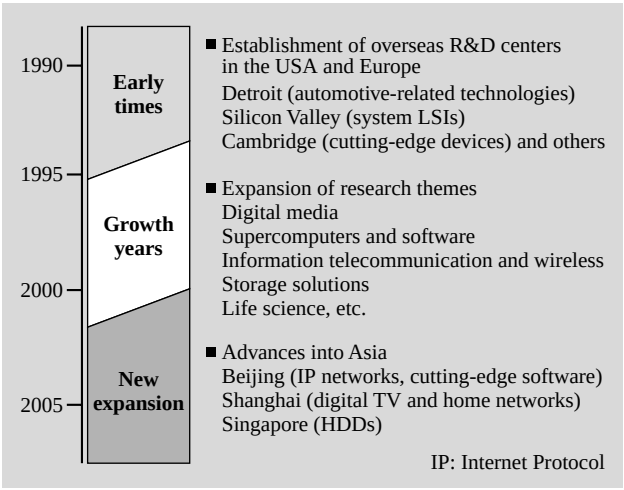


*Fig. 3—History of Hitachi's Overseas R&D Expansion.*
*The history of Hitachi's overseas R&D expansion is shown. Starting from business support and academic cooperation with cutting-edge research bodies in the USA and spreading recently to, first, China and then the rest of Asia, Hitachi's research network has expanded into a global research organization.*

In August 2005, a laboratory was inaugurated in Singapore, and a research partnership framework with national research centers and universities—focused on the HDD (hard disk drive) field—was established. With HDD production sites throughout South East Asia, Hitachi is aiming to fully utilize these collaborative R&D achievements in order to improve product performance and reliability.

## EXAMPLES OF ACTIVITIES IN HITACHI'S OVERSEAS R&D LABORATORIES

### HDD Technology

In 1956, the world's first HDD was developed at IBM's San Jose Research Center. This HDD—named 305 RAMAC*—was composed of 50 layers of magnetic disks. It had a capacity of 4.4 M bytes, a recording density of 2,000 bit/in$^2$, weighed in at a cost of 10,000,000 dollars per gigabyte, and was as big as a refrigerator. In the 50 years that have passed since then, technology has made striking advances and, accordingly, the 2.5-inch HDD used in current notebook PCs has a capacity of 100 gigabytes, a recording density of 135 gigabit/in$^2$, weighs in at a cost of a dollar per gigabyte, and is small enough to fit in the palm of a hand. To put it another way, recording density of HDDs has improved by eight digits in 50 years.

Today, the application field of HDDs is expanding rapidly from being not only mounted in computers but also in consumer electronics (like video cameras and portable devices) as well as in automobiles. In line with this trend, as well as increasing data-storage capacity, strengthening security by data encryption and improving reliability in terms of operational assurance under high and low temperatures are being demanded.

Having about 125 researchers, the San Jose Research Center (SJRC) has constantly led the world in developing HDD technology since the IBM era. Since January 2003, as a research laboratory of Hitachi Global Storage Technologies (Hitachi GST), SJRC has been performing research in close contact with six of Hitachi's domestic corporate laboratories, Hitachi Storage Mechanics Laboratory (HSTM) in Singapore, and HCL in Cambridge. The broad research fields being covered range from improving production yields to technical development of products for launch in three to five years time (such as "patterned media") and future technologies (such as 3D semiconductor memory devices). As for a recent achievement, development of perpendicular magnetic recording (which can improve recording density massively in comparison with conventional methods) can be cited here. HDDs applying this new recording method were released onto the market in May 2006.

### Automotive-related Technologies

Our overseas research center for automotive-related fields is sited in Hitachi's automotive business division in the heartland of motor industry. In the USA, the Automotive Products Research Laboratory (APL) was set up in 1989, and in Europe, the Automotive Research and Development Laboratory (ADL) was set up in Munich and Paris in 2005. Contributing to product development while tackling various technical challenges, these labs are performing R&D aimed at supporting our automotive business.

For efficiently and designing complex mechatronics control systems of motor cars with certainty, model-based development (that is, modeling each component in detail, putting components together, and simulating the combinations) is widely used by car manufacturers. At APL, development of part models and improvement of simulation technology are being tackled.

Moreover, navigation systems already in practical use in Japan (which statistically utilize traffic information) are being deployed in the USA and Europe. These systems are customized to handle the different formats of traffic information in each country, and evaluation testing of their effectiveness is underway.

In addition, empirical research under actual environments in which vehicles run is being performed. Example research themes include analysis and control of engine "knock," "safe running control" utilizing image-recognition technology, and security systems using biometrics.

In 2005, aiming at collaborative research between business and universities, a new materials research laboratory was set up at APL. At this laboratory, the latest welding equipment (such as FSW: friction-stir welding) and materials-analysis instruments, reliability-evaluation devices, and simulators are available, and these services can be harnessed for optimization of casting processes and quality improvement.

In addition to the above, ADL is an active member of AUTOSAR (Automotive Open System Architecture) consortium, contributing to "opening up" the software embedded in car systems and responding to

* RAMAC is a registered trademark of the International Business Machines Corp. in the U.S.

standardization trends. And ADL is engaged in research on "software recycling" technologies through cooperation with academia and business.

In China, to facilitate transportation during the BEIJING 2008 Olympic Games, a traffic information system using a "probe-car method" is being developed in close cooperation with a national project, and a construction of system for actual practical application is currently being attempted. Moreover, centering on collaborative research with universities, research on materials for creating environmentally-friendly cars and on making use of abundant raw materials has started.

Performing R&D by making best use of the respective strong points of each research center in the way described above is becoming a characteristic of Hitachi's automotive research.

### Information-communication-related Technologies

In China, where the continuing economic growth is impressive, development of the information-communication infrastructure is progressing at a speed without parallel in any other country. For example, the number of telephone subscribers is at 700 million, and the number of mobile-phone subscribers has reached 400 million. Moreover, the number of Internet and broadband-Internet subscribers has reached number two in the world and is only second to the USA. With yearly growth of 90% continuing, it is certain that by the second half of 2006 China will overtake the USA in terms of these subscribers.

With a budget of 170 million dollars for setting up an IPv6 (Internet Protocol version 6) network to cover the whole of China by the end of 2006, the China Next-Generation Internet (CNGI) Project was launched in 2003. When completed, this IPv6 network will be the biggest in the world. Participating in this project are a great many people from government agencies and telecommunications carriers as well as researchers from universities and research institutes.

Aiming to expand our business in China under these circumstances, Hitachi established Hitachi (China) Research and Development Corporation, which is performing R&D on products aimed at the Chinese market through collaboration with universities and telecommunications carriers.

With Tsinghua University in Beijing, in 2001, Hitachi (China) Research and Development Corporation set up an alliance research laboratory for joint research. Recently, research on next-generation wireless-communication technology, such as MIMO (multiple-input multiple-output) and OFDM (orthogonal frequency-division multiplexing), is being tackled. Moreover, since 2004, collaborative research with Shanghai Fudan University—on themes in the field of network management such as high-level system-operation management and SOA (service-oriented architecture)—has been progressing.

Although China's present role as "the world's workshop" is often emphasized, China's future role as "the world's brains" will become increasingly important. Accordingly, as the technological hub for the 100 or so Hitachi companies making forays into China, Hitachi (China) Research & Development Corporation will continue to advance product development aimed at the Chinese domestic market as well as global markets.

### Cutting-edge-device-related Technologies

With the goal of creating electronic devices and optical devices based on completely new concepts, Hitachi Cambridge Laboratory (HCL) was established at the Cavendish Laboratory of the University of Cambridge in 1989. Up till now, HCL has inspired new technological directions such as research on the ultimate low-power-consumption, highly integrated devices and definitive single-electron devices At present, research activities in fields such as "spintronics," quantum-information processing, and organic nanoelectronics are being advanced.

In the field of spintronics, through collaborative research with the University of Cambridge, The Academy of Sciences of the Czech Republic, The University of Nottingham, Texas University, in 2005, HCL experimentally demonstrated the "Spin Hall Effect" for the first time since being theoretically calculated in 1971. This demonstration focused the world's attention on opening up a route to realizing new low-power memory devices utilizing spintronics. What's more, in a collaborative study with the University of Nottingham, HCL successfully demonstrated operation of a nano-scale magnetic sensor (with a size of 30×30 nm). It is anticipated that this sensor technology will be applied to magnetic heads of future ultra-high-density HDDs and magnetic-memory devices.

As a completely new computer science based on the theory of quantum mechanics, quantum information processing has the hidden possibility of initiating a "paradigm shift" in information-processing fields—such as quantum communication (which uses

quantum encryption that can detect eavesdropping) and quantum computers (which can bring about exponential increases in information-processing power).

As for a quantum computer, elements known as "quantum bits" (or "Qubits") become the elemental parts of a system. The unit of information in conventional computers (namely, a "bit") can exist as either a "1" or a "0." In contrast, according to the theory of quantum mechanics, a bit can exist in the "1" and "0" states at the same time. Moreover, multiple states are expressed due to quantum entanglements between bits. Accordingly, with quantum computing, a great number of calculations can be executed at the same time during one calculation procedure. With the realization of quantum computing, it is possible that existing encryption systems (which maintain security through massive amounts of decoding calculations) will be broken into. In that case, the need for quantum-encryption systems will grow.

At HCL, simplicity of practical applications in the future is being watched closely, R&D on semiconductor quantum bits using silicon (by making use of conventional semiconductor-process technologies) is progressing, and fundamental experiments were completed successfully in 2005. Furthermore, aiming toward realization of quantum computing, collaborative research between research centers at the University of Cambridge, the University of Surrey, and the National Physical Laboratory, UK, to name but a few, is continuing.

### Design

With design centers in the USA, Europe, and Asia, Hitachi is providing design suited to the cultures and national characteristics of those regions through cooperation with the design headquarters and research centers in Japan. For example, in Europe, Hitachi Design Centre Europe (HDCE) was established in Milan, Italy—at the center of design trends in fashion, furniture, cars, etc. And since 1989, HDCE has been involved in research on design and design activities in diverse fields like industrial design, graphic design, Web design, interaction design, and information design.

Design is not purely about providing external quality only; it is also a creative process for comprehensively handling functionality, ergonomic factors, and product lifecycles while embodying technologies in commercial products. Furthermore, evaluation of designs is deeply rooted in the cultures and national characteristics of these regions. And in regions where many cultures are grouped together in the manner of Europe, the role of a designer as the "mouthpiece" of consumers is important. In addition, design is the task of optimization through collaboration with technical experts and engineers.

Starting off with market research, the actual and rather complicated design process moves on to analysis of the different product connotations from the viewpoints of users in different regions, then looks at the possibility of investigation and optimization from the technical aspect, and finishes with proposal, evaluation, and actualization of design concepts.

Moreover, in the field of interaction design, new product concepts are being put forward by making good use of collaboration with R&D groups in Europe. To put that concretely, one such concept that can be cited here is gesture-type interaction design for interactive public-announcement systems using large-size flat-panel displays. The result of efforts to use a prototyping method based on a usage scenario and to present an image of the concept in an easy-to-understand way is being highly appraised.

## CONCLUSIONS

This article described representative research activities making use of the special regional characteristics of Hitachi's overseas research centers. It makes it clear that R&D in various forms is being carried out at these centers. As well as pursuing research activities at our overseas research centers, Hitachi is actively engaged in academic-industrial collaborations in forms such as researcher exchanges and sponsored research at overseas universities and research establishments. From now onwards, we would like to see R&D continue to be conducted in close cooperation with overseas operations and push Hitachi's strategic global expansion.

## ABOUT THE AUTHORS

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*Joined Hitachi, Ltd. in 1971, and now works at the Global R&D Operation Office, the Research and Development Group. He is currently engaged in supervising overseas R&D strategies. Dr. Abe is a member of Information Processing Society of Japan (IPSJ), the Institute of Electronics, Information, and Communication Engineers (IEICE).*