

道程

**Our Journey**

DOUTEI

**The Fifty-Year Progress of *Harmonic Drive Systems Inc.***

**Fifty-Year History**

## Messages on the Occasion of the Publication



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**Mitsumasa Ito**  
Chairperson, Representative Director

In November 2020, Harmonic Drive Systems, Inc. celebrated its 50th anniversary. I would like to express my sincere gratitude to the early pioneers who worked hard to lay the foundation of the company at the time of its founding, our employees and their family members, our affiliated companies and trading partners, and the residents and city officials of Azumino City. The company could not have come this far without their efforts and support.

In February 1970, I met with Kiichiro Hasegawa, then Vice President and Representative Director of Hasegawa Gear Works, Ltd., in Frankfurt am Main, Germany. A friend of mine introduced me to him. He was stopping by on his way back to Japan via Europe after visiting the United Shoe Machinery Corporation, headquartered in Boston, the U.S.

He seemed to be very driven in his efforts to achieve success. He was full of confidence when he spoke. With a sample in his hand, he enthusiastically talked about the global strategy for HarmonicDrive® and the matters he discussed with the United Shoe Machinery Corporation. I became convinced that his comprehensive and global business strategy, if successfully implemented, would develop into a wonderful business. This was my encounter with Kiichiro Hasegawa and HarmonicDrive®.

In June of that year, Kiichiro Hasegawa stopped by Frankfurt again on his way back from Boston. As a result of the discussion, Hasegawa Gear Works, Ltd. and the United Shoe Machinery Corporation came to a formal agreement to establish joint ventures in Japan and Germany. As an employee of Hasegawa Gear Works, Ltd., I was then assigned to start preparations for the establishment of the German joint venture and to manage the company after the establishment.

Fifty years have passed since then. Initially, I did not fully appreciate the value of HarmonicDrive® because I regarded it as a type of speed reducer. The 1970s for me was a decade of trial and error. I became aware of its unlimited potential for opening the path to the future around the late 1970s, when the precision control market emerged as a new market in Germany in response to customer demand because of the presence of HarmonicDrive®. It was by sheer luck that I encountered this product in my life, for which I feel profoundly grateful.

The precision control market has been created and still exists because of the presence of HarmonicDrive®, thanks to the enormous efforts of our early pioneers and employees as well as the support from our affiliated companies, trading partners, and many other people involved. With great pride in this fact, we remind ourselves of our mission to further develop the precision control market and contribute to society in the next 50 years.



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**Akira Nagai**  
President, Representative Director  
Chief Executive Officer

On November 10th, 2020, Harmonic Drive Systems, Inc. celebrated its 50th anniversary. I would like to express my heartfelt gratitude for your patronage and support, which has helped the company reach this anniversary.

The 50-year history of the company is comprised of a collection of daily archives of how our past and current employees overcame countless challenges and difficulties in development, manufacturing, and sales.

We should also remember that warm support from their family members, our customers, and affiliated companies helped them to achieve it. Personally, I feel blessed to have the opportunity to celebrate this milestone with you as President.

The events we experienced over the past 50 years are chronicled in detail in the history of the company and the history of technology celebrating the 50th anniversary. Japan's as well as the world's, the company's history is not only a publication celebrating a milestone, but the world's industrial history of precision speed reducers, for which I feel tremendously proud.

The company's history is, in a single sentence, one of a company that went all out to develop the current family of HarmonicDrive® products based on the patent filed by C. Walton Musser in 1955. One of our major objectives is to consider whether and how this extraordinary invention will survive in the future.

Charles Darwin, the father of the theory of evolution, reportedly said "It is not the strongest of the species that survives. It is the one that is most adaptable to change." HarmonicDrive® experienced a dark period in which it struggled to find applications for almost 10 years. Later, applications of our products started to spread rapidly after hydraulic drive systems for industrial machines were replaced with electric motor drive systems. Such applications include, for example, machine tools, industrial robots, semiconductor manufacturing equipment, liquid crystal manufacturing equipment, and in the 21st century, assembly lines for mobile phones, PCs, and tablets, as well as surgical robots. The list is endless. The primary reason that the company has survived until now is that it has successfully been adapting to changes in the circumstances surrounding it.

As we celebrate our 50th anniversary, we will consider this year to be the first year of the next 50 years rather than our 51st year, rethink the roles of our products in the industry and in society, and work on proper manufacturing with QCDS in mind more than ever.

Lastly, I would like to express my gratitude to everyone who has been guiding us. I appreciate your continuous support and guidance.

# Management Philosophy

**Akira Nagai**  
Representative Director, President

The management philosophy that sustains our company and enables us to grow can be described as follows.

## I. Respect for the Individual

HDSI aspires to be a company where the rights of every individual employee are respected, and where individuals can pursue a meaningful, cultural, and worthwhile life.

We will make HDSI a company that believes in each employee's aspirations, supports independent activities, creates an environment where employees can maximize their abilities through work, and where abilities and performance are rewarded.

## II. A Meaningful Company

HDSI wants to be recognized as a meaningful, superior company which manifests creativity, has personality and distinctive characteristics, and whose management foundation is based on ceaseless research and development activities and a constant emphasis on quality—a company where the entire organization finds meaning in making utmost efforts.

## III. Coexistence and Co-prosperity

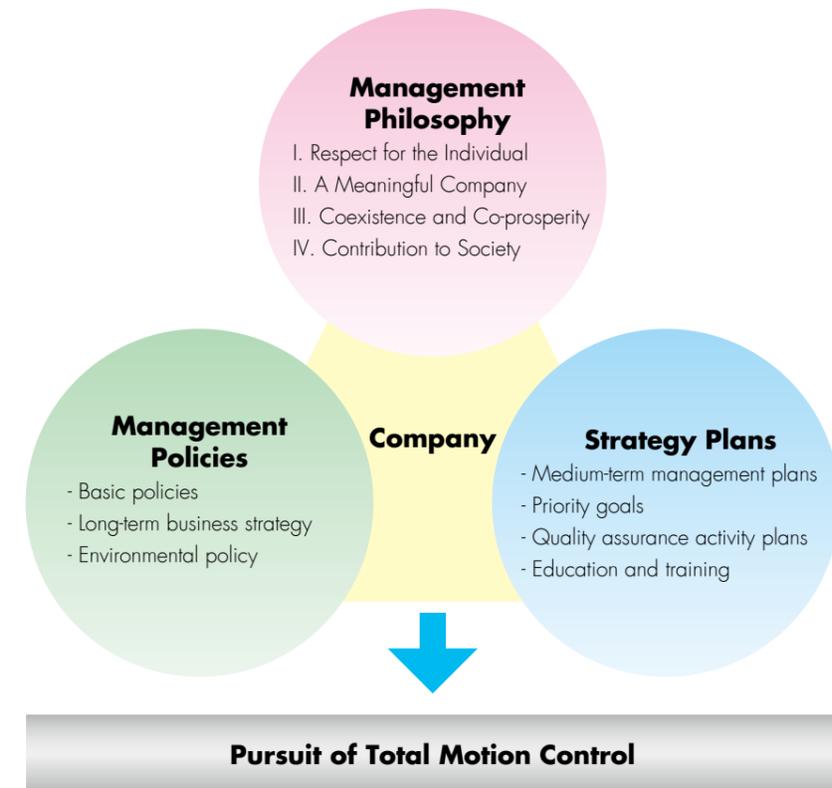
HDSI is supported by many different parties including our employees, customers, shareholders, materials and parts suppliers, affiliated companies and trading partners.

We make our best efforts to create attractive products, services, compensation, working environments, and trading relations to satisfy all these concerned parties.

## IV. Contribution to Society

HDSI broadly contributes to society and industry through our corporate activities as a good corporate citizen.

The products and services we provide directly and indirectly contribute to the betterment of society. We aspire to be a company that helps to improve the environment and the quality of the communities where we are located.



Our management philosophy sets the unchanging goals that we want to achieve through the corporation.

As means to fulfilling our management philosophy we have management policies, which change over time to adapt to the current realities.

For carrying out those management policies we draw up strategy plans.

These three elements, our management philosophy, management policies, and strategy plans, make up our management plans, through which we are pursuing Total Motion Control.

**Speed Reducers for Precision Control**

# HarmonicDrive®

**Speed Reducers**

**CSG Series**



Component/Cup Type, High-Torque Type

**CSD Series**



Component/Cup Type, Super Flat Type

**CSF Series**



Component/Cup Type, Standard Type

**SHG Series  
SHF Series**



Component/Silk Hat Type, High-Torque Type  
Component/Silk Hat Type, Standard Type

**FBS-2UH Series**



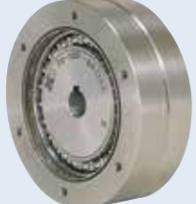
Unit/Small Outer Diameter, Large Hollow-Shaft Type

**FB Series**



Component/Pancake Type, Standard Type

**FR Series**

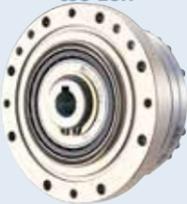


Unit/Super Flat, High Load Capacity Type

**CSG Series**

**CSD Series**

**CSG-2UH**



Unit/High-Torque, Light Weight Type

**CSG-2UK**



Unit/Seal Structure, High-Torque Type

**CSD-2UH**



Unit/Super Flat, High Load Capacity Type

**CSD-2UF**



Unit/Super Flat, High Load Capacity Type

**CSF Series**

**SHG/SHF Series**

**CSF-2UH**



Unit/Standard, Light Weight Type

**SHG-2UH/SHF-2UH  
Hollow Shaft Type**



Unit/High-Torque Hollow Shaft, Light Weight Type

**SHG-2UJ/SHF-2UJ  
Input Shaft Type**



Unit/Hollow Shaft, Light Weight Type

**SHG-2SH/SHF-2SH  
SHG-2SO/SHF-2SO  
Simple Type**



Unit/High-Torque Hollow Shaft, Light Weight Type

**CSF supermini Series**



Gear Head Type/Low Capacity Type

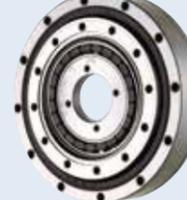
**SHD Series**

**SHD-2UH**



Unit/Super Flat, Hollow Shaft Type

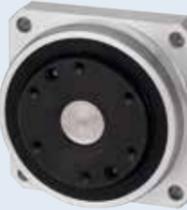
**SHD-25H**



Simple Unit/Super Flat, Hollow Shaft Type

**CSF mini Series**

**CSF-2UP**



Unit/Super Flat, High Stiffness Type

**CSF-1U**



Unit/Compact Double Shaft Type

**CSF-2XH**



Gear Head Type/Low Capacity Type

**FD Series**

**FD Series**



Unit/Phase Adjustment Unit, Standard Type

**Planetary Speed Reducers**

# HarmonicPlanetary®

**Speed Reducers**

**HPGP/HPG Series**



Planetary Speed Reducer/High-Torque, Standard Gear Head Type

**HPG-R Series**



Planetary Speed Reducer/Helical Gear Type

**HPG-RA Series**



Planetary Speed Reducer/Orthogonal Shaft Type

**HPG-U1 Series**



Planetary Speed Reducer/Input Shaft Unit Type

**HPF Series**



Planetary Speed Reducer/Hollow Shaft Unit Type

**HP-F Series**



Planetary Speed Reducer/Gear Head Unit Type

**Mechatronics Products**

# MECHATRONICS

**Actuators**

**Rotary Actuators**

**SHA Series (CG Type)**



AC Servo Motor/  
Hollow Shaft, Flat Type

**SHA Series (SG/HP Type)**



AC Servo Motor/  
Hollow Shaft, Flat Type

**FHA-C mini Series**



AC Servo Motor/  
Compact, Hollow Shaft, Flat Type

**FHA-C Series**



AC Servo Motor/  
Hollow Shaft, Flat Type

**RSF supermini Series**



AC Servo Motor/  
Ultra-Small Cylinder Type

**RSF-B mini Series**



AC Servo Motor/  
Compact Cylinder Type

**RSF/RKF Series**



AC Servo Motor/  
Compact Cylinder Type

**RH Series**



DC Servo Motor/  
Compact Cylinder Type

**FLA Series**



Brushless DC Servo Motor/  
Super Flat, Light Weight Type

**Linear Actuators**

**LBC Series**



AC Servo Motor/  
High Driving Force, Positioning Type

**LA Series**



DC Servo Motor/  
Low Driving Force, Positioning Type

**LAH-46 Series**



DC Servo Motor/  
Medium Driving Force, Positioning Type

**KDU Series**



Direct Drive Motor/  
High Accuracy Type

**HMA Series**



AC Servo Motor/  
Hollow Shaft, Flat Type

**Motors**

**LSA Series**



High Accuracy, Rapid Response

**Optical Galvano Scanners**

**Micro Encoder Series**



Super Compact, High Resolution

**Sensor Systems**

Harmonicsyn<sup>®</sup>

**Servo Drivers**

**HA-800A Series**



For AC Servo Motor/Position, Speed, and Torque Control

**HA-800B Series**



For AC Servo Motor/Compatible with the Open Field Network



**HA-800C Series**



For AC Servo Motor/Compatible with the Open Field Network



**HA-680 Series**



For AC Servo Motor/Position, Speed, and Torque Control

**HA-680ML Series**



For AC Servo Motor/Compatible with the Open Field Network



**HA-770 Series**



For Direct Drive Motor/Position Control Only

**HA-360 Series**



For DC Servo Motor/Position Control Only

# Locations

## Global Network



**SAMICK ADM CO., LTD.**

**Korea**



**Harmonic Drive Systems (Shanghai) Co., Ltd.**  
(exterior view of the building)

**China**



**Harmonic Drive SE**

**Germany**



**Harmonic Drive L.L.C.**  
**HD Systems, Inc.**

**U.S.A.**



**Harmonic Drive Systems Inc. Taiwan Representative Office**  
\* Representative office of Harmonic Drive Systems, Inc. (exterior view of the building)

**Taiwan**



# Locations

## Exterior Views of Major Locations in Japan



**Hotaka Factory**



**Ariake Factory**



**Matsumoto Factory**



**Head Office** (exterior view of the building)



**Toyoshina Factory**

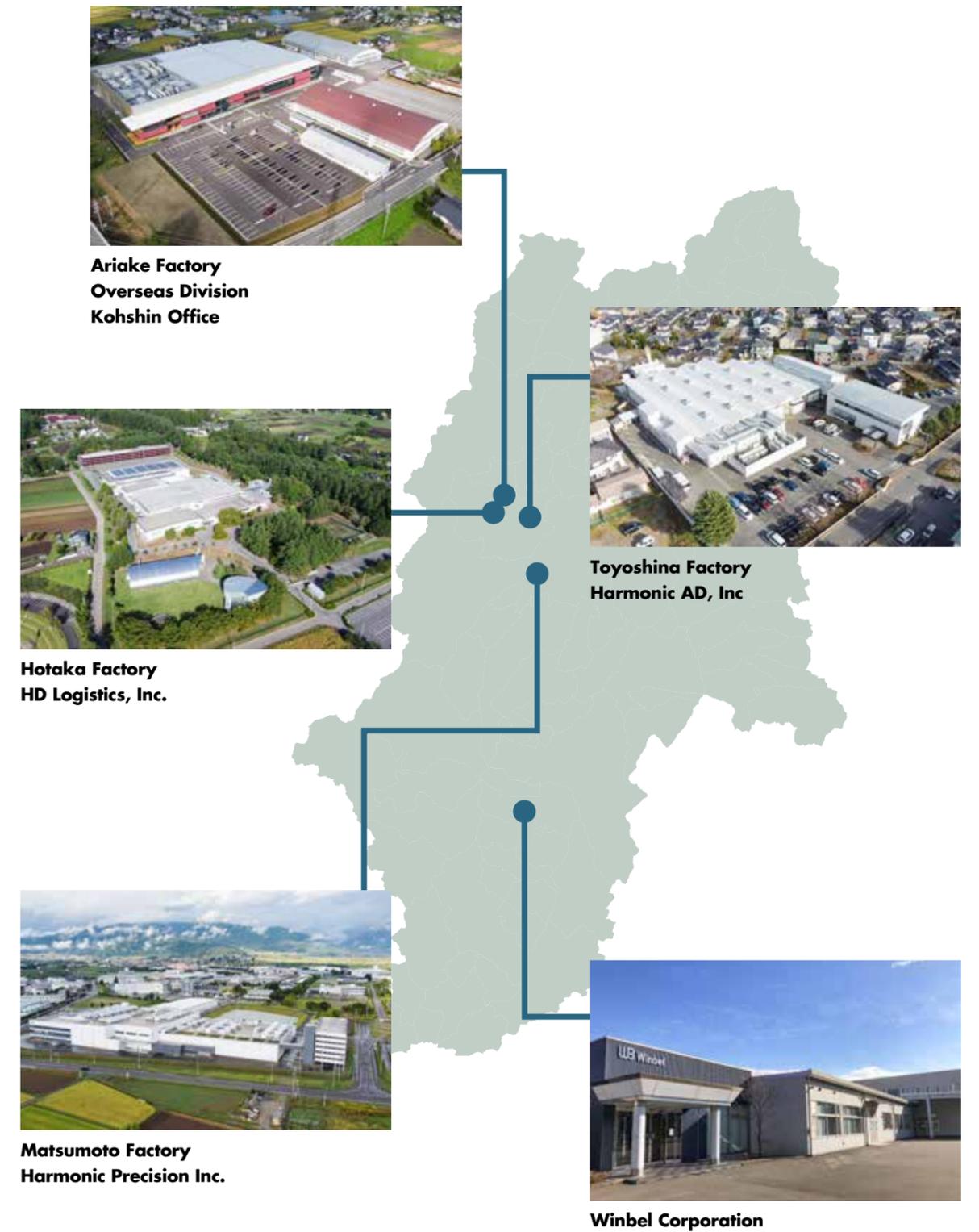
Aerial photographs taken by HDS Radio Control Club

# Locations

## Domestic Network (Japan)



## Domestic Network (Nagano Prefecture)



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**Legends**

1. The Fifty-Year History consists of Introduction, Company History, and Appendix.
2. The information contained herein is current as of November 2020 in principle. Some information is current as of the issuance of this publication.
3. Arabic numerals are used in principle with auxiliary units of billion and million.
4. The name of the company is basically referred to as "HDSI."
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Legends

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# Chapter 1: Prehistory

## The Road from Technology Introduction to Domestic Production of HarmonicDrive® during the Years of Hasegawa Gear Works

# 1962–1969

### 1-1 Establishment of Hasegawa Gear Works and Its Encounter with HarmonicDrive®

At the beginning of the history of the company, Hasegawa Gear Works was established by Kiyoji Hasegawa in 1911. With gear cutting machines that were state of the art at that time, the company started its operations at a plant in Furukawa Bashi, Minato-ku, Tokyo.

In 1935, Kichisaburo Hasegawa became the second president of the company. In 1937, the company built

its main plant in Minami-Rokugo, Ota-ku, Tokyo. This established its foundation as a manufacturer of large gears. During the postwar reconstruction period, the company started to design and manufacture large gear speed reducers for the steel, shipbuilding, cement, and pulp and paper industries where production continuously increased. The company established a solid position as a manufacturer of large speed reducers.

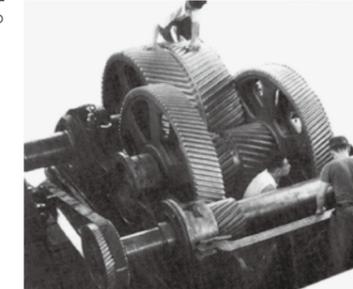
At the time, there was a person who was concerned about Hasegawa Gear Works that started to take a defen-



Gear cutting plant of Hasegawa Gear Works, Ltd. soon after the relocation to Minami-Rokugo, Ota-ku



Hiroshi Kameda and Shoji Hata, during the years of designing large speed reducers



A large speed reducer

sive position. It was Vice President Kiichiro Hasegawa, a son of Kichisaburo Hasegawa. In the fall of 1961, Kiichiro Hasegawa attended a workshop held by Hitachi, Ltd., which was one of their main customers. He saw the plants of Hitachi quickly evolving as a result of the introduction of foreign technology. He said, “I wonder if the company will be okay as it is. We may need to open some new avenues.” Based on his experience in studying the latest managerial theories in the Faculty of Politics and Economics at Gakushuin University, he also felt that something important was missing in just protecting and fostering the business developed by his grandfather and father.

Then came a turning point. At the beginning of 1962, Kichisaburo Hasegawa requested that Kiichiro Hasegawa visit his industry peers in the U.S. and Europe and think about the future of the company after consultation with Russell C. Ball, president of the American Gear Manufacturers Association, who was visiting Hasegawa Gear Works.

In November of that year, when foreign countries were still regarded as far distant, Kiichiro Hasegawa set off for a study tour in the U.S. and Europe with a small tape

recorder in hand. This tour in search of future technology lasted for about 80 days, as in the film *Around the World in Eighty Days*. He visited 37 leading companies in the U.S., the U.K., West Germany, France, and the Netherlands, and met with a total of about 180 people. He successfully collected information about the management, technology, and human resources of each company, but could not obtain any significant results in terms of seeking new technology, which was one of his goals.

After Kiichiro Hasegawa came back to Japan, Kichisaburo Hasegawa created the Circle Ha Group consisting of elite members selected from the Sales, Design, Development, Manufacturing, Material, and Finance Departments. Circle Ha was named after “Hasegawa.” Under the leadership of Kiichiro Hasegawa, the Circle Ha Group launched the “New Product Exploration Program,” which had a solid framework for new product exploration, creating a system for narrowing down candidates in a systematic manner.

In October 1963, the company requested Graham Parker Office, a New York-based technology consultant firm, to investigate new technologies. Graham Parker Office asked for the requirements of new technologies to



Hasegawa Gear Works, Ltd.



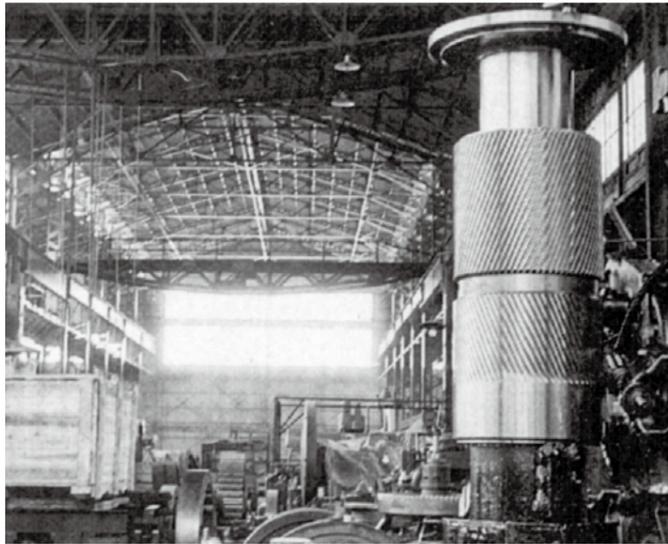
Kiyoji Hasegawa, founder



Kichisaburo Hasegawa, president of Hasegawa Gear Works



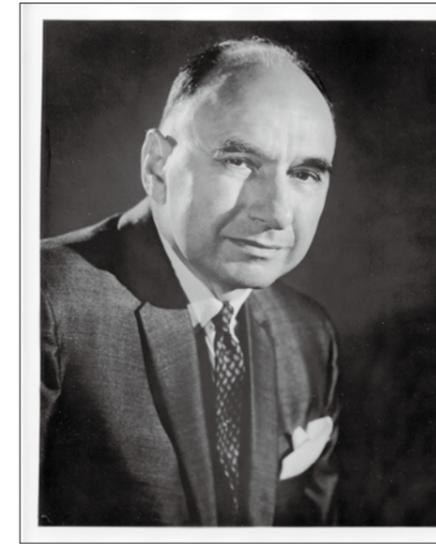
Kiichiro Hasegawa, vice president



Gear cutting of a double helical gear for a geared marine steam turbine



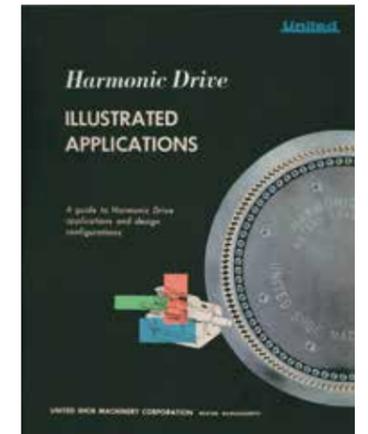
Atsuo Tokoro (\*)



C. Walton Musser (1909–1998)



Machine Design, an American mechanical engineering magazine



ILLUSTRATED APPLICATIONS (USM)

seek, and the company presented the following requirements:

- (1) **The product shall have a high price per ton.**
- (2) **The product shall belong to a group of technologies within the range that can be assessed by engineers of the company.**
- (3) **Even large companies, with their capital strength, cannot catch up in the technology.**
- (4) **The product shall be marketable to customers of the company.**
- (5) **The product shall be able to take advantage of the manufacturing capabilities of the company.**
- (6) **The product shall be covered by patents.**
- (7) **The product shall be commercializable with the capital strength of the company.**

In April 1960, Shoichi Ishikawa, an engineer at Hasegawa Gear Works, found HarmonicDrive® manufactured by USM (the United Shoe Machinery Corporation). He read an article on an advertising page of Machine Design, an American mechanical engineering magazine, and took an interest.

He said to Hiroshi Kameda, one of his peer engineers, “I found this interesting speed reducer. I’d like to know

more about its principle.” Kiichiro Hasegawa said, “We were looking for something extraordinary. HarmonicDrive® was so extraordinary that I doubted if we really could manufacture such a thing.”

It is no wonder that Shoichi Ishikawa and Kiichiro Hasegawa thought so. Generally speaking, a gear refers to an extremely hard piece of metal with cut teeth. It is a rigid body. Any gear with deflected or weakened teeth is useless. However, HarmonicDrive® had a structure that used thin and flexible parts and still worked as a gear, which defied intuition.

In March 1964, the consultant firm Graham Parker Office presented the new technologies of 12 potential candidate companies. HarmonicDrive® was not one of them. However, the company’s engineering team decided to request Graham Parker Office to investigate USM after a great deal of consideration of the future potential and marketability of HarmonicDrive® as a new technology. Apparently, Kiichiro Hasegawa and Hiroshi Kameda had already made up their minds to introduce it at that point. In an interview on the early years of the company conducted for compiling the company’s history, Hiroshi Kameda said, “The technology of HarmonicDrive®

looked incredibly good to me. I thought it was a deal.” Atsuo Tokoro, a representative of Graham Parker Office based in Japan, was involved in the entire process from the investigation of new technologies to technology partnership. Later, he joined Hasegawa Gear Works, participated in the establishment of Harmonic Drive Systems Inc., and became president of the company in 1979.

Kiichiro Hasegawa and Hiroshi Kameda, with a consultant from Graham Parker Office, went to the U.S. to examine the technology on site. They visited USM and looked at actual HarmonicDrive®, samples, and drawings. They were impressed with a public relations booklet featuring a collection of applications. Kiichiro Hasegawa and others then called the booklet (*ILLUSTRATED APPLICATIONS*) a “dream book.” This was because the booklet contained a wide variety of applications of HarmonicDrive®, most of which were imaginary creations.

The device, invented by the gifted American inventor C. Walton Musser, achieved high reduction ratios with a simple mechanism by using the elasticity of metal. Although seemingly contrary to intuition in engineering, it was an advanced and revolutionary power transmission device that produced a number of advantages by applying

the mechanics of elasticity. They took particular note of the following four advantages:

- (1) **Mechanism consisting of only three components: a wave generator, a flexspline, and a circular spline**
- (2) **High reduction ratios of 1/80 to 1/320 obtained with one stage**
- (3) **Superior efficiency due to low circumferential speed and low friction loss of the teeth**
- (4) **Up to about 10% of the teeth meshing. In addition, it produces high torque capability for its size and volume because stresses are minimal due to the surface contact of the teeth.**

Based on its structure, they believed that it would have a broad range of applications: large sizes for driving parabolic antennas at ground stations for space telecommunications, and small sizes for power tools and control systems for precision equipment. The details will be discussed in the technology section.

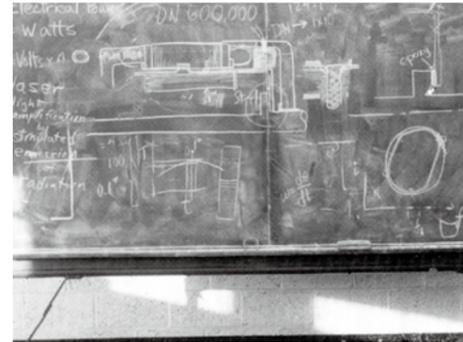
## 1-2 Approval of the Technology Partnership Agreement for HarmonicDrive® by the Japanese Government

HarmonicDrive® was described as “too good to be true” in the advertisement films of USM. Fascinated by

\* Atsuo Tokoro, Director (1970–1973), Executive Director (1973–1976), Vice President (1976–1979), Representative Director, President (1979–1994), Representative Director, Chairperson (1994–1997), Adviser (1997–2002), passed away on April 20, 2015.



From left to right: Kameda, Scott (USM), Ishikawa, and Arita



A lecture on RESPONSYN



The BOAC flight that they took for training



From left to right: Kameda, Hasegawa, Ishikawa, and Arita



Shoji Hata

the innovative principle as depicted by this phrase, Kiichiro Hasegawa and others decided to introduce it on the very day that they visited USM, and also because they heard that their Japanese competitors would visit the following week. The price of the exclusive right was, according to USM, “an initial payment of 50,000 dollars” and “5% royalties on sales.” With 6,000 dollars’ worth of traveler’s checks in hand, Kiichiro Hasegawa suggested, “I will pay 5,000 dollars in cash today. Why don’t we sign a provisional exclusivity contract?” “They became visibly breathless in that moment,” he later said. He also heard the sales manager whisper to the division director, “Boss, we should make up our mind.”

Actually, although the Harmonic Drive Division of USM had already spent a large amount of development funds, they only developed sporadic applications, still being unsuccessful in building a strong track record in the industrial fields. Apparently, they were facing criticism from others as a result. Kiichiro Hasegawa and Hiroshi Kameda visited them out of the blue, heard some details for half a day, and asked for a technology partnership. “They must be happy and puzzled at the same time,” Kiichiro Hasegawa said in retrospect.

At the beginning of June 1964, Hasegawa Gear Works and USM signed a technology partnership agreement for manufacturing, use, and sales in Japan. In those times, the Foreign Investment Act required government approval for signing an international technology partnership agreement. As such, the technology introduction agreement for manufacture, use, and sales (including import) of the HarmonicDrive® mechanism in Japan was reviewed by the Foreign Investment Council, an advisory body to the prime minister. As a result, the company obtained government approval dated November 10, 1964, offering the prospect of domestic production of HarmonicDrive®.

### 1-3 Establishment of the Harmonic Drive Division and Technical Training

However, unconventional approaches to the production process, technology, and sales were required to start the production of HarmonicDrive®. To this end, the company established the Harmonic Drive Division on December 21, 1964. This organization was the starting point of HDSI. It is worth mentioning that it was Shoji Hata who got HarmonicDrive® off the ground by acting a representative in Japan. Shoji Hata played the most

active part in manufacturing.

In January 1965, the “Harmonic Drive Technical Training Team” was created, which visited the U.S. A team of four, namely Vice President Kiichiro Hasegawa, Manager of the Development Department Hiroshi Kameda, Chief of the Engineering Section Shoichi Ishikawa, and Chief of Production Engineering Mitsuo Arita stayed at USM for about one month from early January. They learned all aspects of the technology, including the principles of HarmonicDrive®, patents, strength calculation, design methods, fabrication methods, and inspection and measurement methods.

They had gained an understanding of the operation principles of HarmonicDrive® by assembling a cardboard kit of HarmonicDrive® obtained from USM before visiting the U.S. On December 11, 1964, they successfully completed a test run of the first prototype, and later achieved continuous operation. They succeeded in prototyping even before they learned specific techniques from USM. Their superior technological capabilities at the time later expedited the commercialization after the technology introduction. They did not have an actual unit in hand and were struggling to find its applications. Sending

the Technical Training Team offered the prospect of its commercialization.

As a side note, in those times, visiting the U.S. itself was an adventure. At the airport, the staff members of Hasegawa Gear Works saw them off by holding a banner and shouting, “Banzai!”

They also met with Musser in the U.S. They heard firsthand his stories of difficulties in the development, and exchanged opinions about its applications.

Shoichi Ishikawa then pointed out a contradiction with the theory of meshing as described in the patent document. There was something theoretically impossible. Musser replied, “Mr. Ishikawa, you are brilliant. Well noticed.” In fact, the U.S. patent examiner did not understand the theory of flexible meshing and did not approve the patent. In response, Musser acquired a patent by using the theory of inflexible meshing. In Japan, the company successfully acquired a patent as a result of the patent document on HarmonicDrive® prepared by Shoichi Ishikawa based on flexible gears.

Hiroshi Kameda said, “I thought he was a real genius” after seeing Musser in person for the first time. He had made a number of achievements, including the invention,



Musser's laboratory

Wall of Musser's laboratory as seen by Kameda



A lecture by Musser



Exhibition at the 6th Tokyo International Trade Fair (Harumi, Tokyo)

design, and manufacture of the recoilless rifle and aircraft personnel catapults.

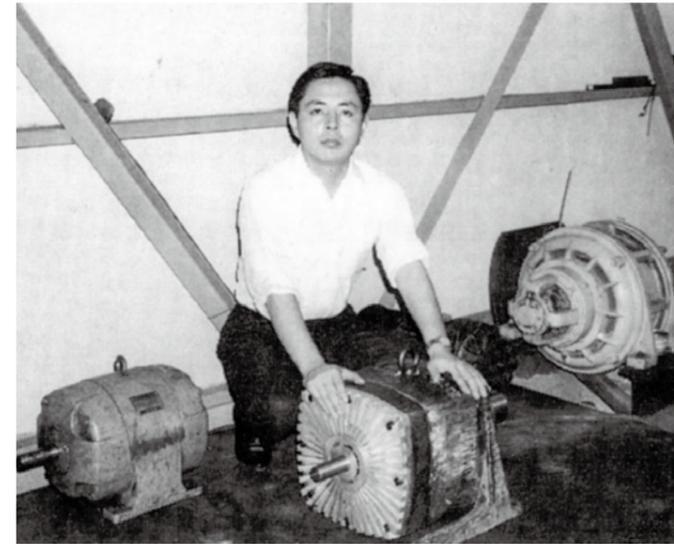
Hiroshi Kameda later told anecdotes about his visit to Musser's laboratory in the U.S., which tell us Musser was a humorous individual. Musser, a music lover, played a tune on a self-made musical instrument, a series of pipes arranged in a musical scale, by hitting it with sticks.

The laboratory had a view of the ocean. When Musser opened the curtain on the other side, Hiroshi Kameda was surprised that there was another view of the ocean, much to Musser's enjoyment. On closer look, it was a painting of the ocean. These events told them that Musser always worked on his development with enjoyment. Immediately after returning to Japan from a fruitful trip in mid-February, the Technical Training Team started to translate the related documents including drawings and specifications. Concurrently, the Production Section started to build production lines with the bare minimum equipment required for production. They proceeded with the procurement of wave generator bearings, materials and tools, examination of processing methods, and manufacture of machining jigs to prepare for production.

#### 1-4 Completion of the First Domestically Produced Unit and Incoming Orders

On another front, while proceeding with the preparations for the production, the members of the Harmonic Drive Division were concerned about the possibility that the mechanical industry might not readily accept HarmonicDrive® because its mechanism was so innovative. Regardless, the Sales Department concluded that their top priority was to see how related industries would respond, and sent catalogs to about 1,500 leading companies selected from 7,000 companies in Japan that they thought were closely linked to power transmission mechanisms, including machinery, electric appliances, and chemical machinery. As a result, they received replies from 1,480 companies, which exceeded their expectation. Encouraged by the response, the sales people started to visit these companies with samples manufactured by USM to take trial orders.

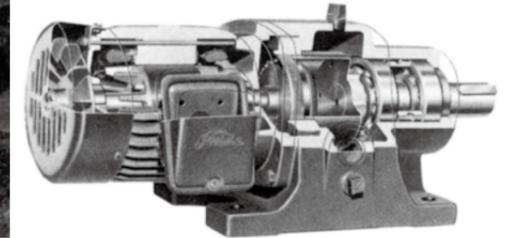
At the same time, they put their energy into promotional activities. In April 1965, they exhibited imported standard products at the 6th Tokyo International Trade Fair held in Harumi, Tokyo. They ended up receiving a



The first unit (for Hitachi, Ltd.) and Kiichiro Hasegawa, vice president (\*)



Turning on the switch of the first unit for the first time



HARMONIC MOTOR®, horizontal type with legs (Type 3)

more-than-expected attention from related industries and manufacturers in Japan. In April 1966, they exhibited panels at the Osaka International Trade Fair. In April 1967, they exhibited a total of 30 units of varying sizes of HarmonicDrive® at the Tokyo International Trade Fair to promote its characteristics on a full scale. These promotional activities gradually gained HarmonicDrive® wide recognition.

The first unit of HarmonicDrive® manufactured in Japan was completed in late July 1965. It was manufactured for Hitachi, Ltd. At the end of October of that year, the company signed a distributor agreement with Mitsui & Co., Ltd. Around that time, the company successfully sold a total of 140 components with its own parts and some imported parts. Needless to say, Kiichiro Hasegawa and others felt great joy about the good start.

Around 1966, the company started the production of "HARMONIC MOTOR®," a geared motor consisting of HarmonicDrive® and a motor, which was adopted for paper machines for paper manufacturing. In July of that year, the company delivered large sizes of Harmonic Drive® to Hitachi Zosen Corporation. It also started to deliver a product for TV camera drive units. It was highly

appreciated for smooth movements of a TV camera as it eliminated noise during movements, which was common in conventional products, as well as backlash (play or clearance in the meshing of gears).

In March 1968, the company developed the double eccentric wave generator and expanded its product lineup to meet customer needs. One example is the actuator for lightweight shutters developed in August 1969. The company signed a basic sales agreement with Sanwa Shutter Corporation and started manufacturing 200 units per month.

It was adopted for many other applications, including mechanisms to drive the minute hands of large clocks, tensile strength testers for testing material fatigue, drive mechanisms for radiotherapy equipment, and drive mechanisms for satellite tracking telemetry and acquisition radars.



Delivered large size 160 to Hitachi Zosen Corporation, which was used for a centrifuge

\* Kiichiro Hasegawa: founder, first president, representative director (1970–1976), adviser (2011–2015), and advisory member (2015–2018), passed away on July 5, 2018

# Chapter 2: Establishment

## The Birth of Harmonic Drive Systems Inc.

# 1970–1978

### 2-1 Establishment of Harmonic Drive Systems Inc.

#### Negotiations to Establish a Joint Venture

As a result of receiving an increased number of orders immediately after starting full-scale production of HarmonicDrive®, Hasegawa Gear Works put effort into expanding its production facilities from 1965 to 1969. The company built a new three-story SRC building with a gross floor area of 1,980 m<sup>2</sup> (partially including office space), and introduced a series of the latest machine tools, including lathes, honing machines, grinding machines, and drilling machines. Understandably, the site area of the Minami-Rokugo factory was limited. As it was virtually impossible to further expand its production facilities, the company started to look for new factory premises.

Around that time, there was an ongoing conversation about establishing a joint venture between Hasegawa Gear Works and USM. The management philosophy of Hasegawa Gear Works included the prospect of entering the international market with the HarmonicDrive® business based on the internationally minded idea that “companies are borderless” that Kiichiro Hasegawa felt during

his “Around the World in Eighty Days” tour. The establishment of a joint venture was critical for the company to bring the idea into shape.

USM wanted to establish a site in the Far East. With Harvard W. Jervis, president, Thomas D. Welch, vice president, and W. N. Bley, vice general manager of British USM visiting Japan in succession, they were actively working toward the establishment of a joint venture.

The idea of establishing a joint venture took shape in a short period of time because their wishes were consistent. In February 1970, Hasegawa Gear Works and USM agreed upon establishing a 50:50 joint venture.

However, at that time, in order for a foreign company to acquire the shares of a Japanese company, it was required to submit an application to the Foreign Investment Council to obtain approval after deliberations. For that reason, they agreed upon establishing the new company in the following steps. First, Hasegawa Gear Works would isolate the Harmonic Drive Division and establish a new independent company as a subsidiary. Concurrently, USM would submit an application to the Foreign Investment Council to obtain approval to acquire its shares. After approval was given, Hasegawa Gear Works



Head Office after being relocated to Roppongi 2-chome, Minato-ku



Interior of the Head Office (Sales Department)



A material handling truck

would transfer 50% of the shares of the new company to USM.

#### Establishment of a New Company

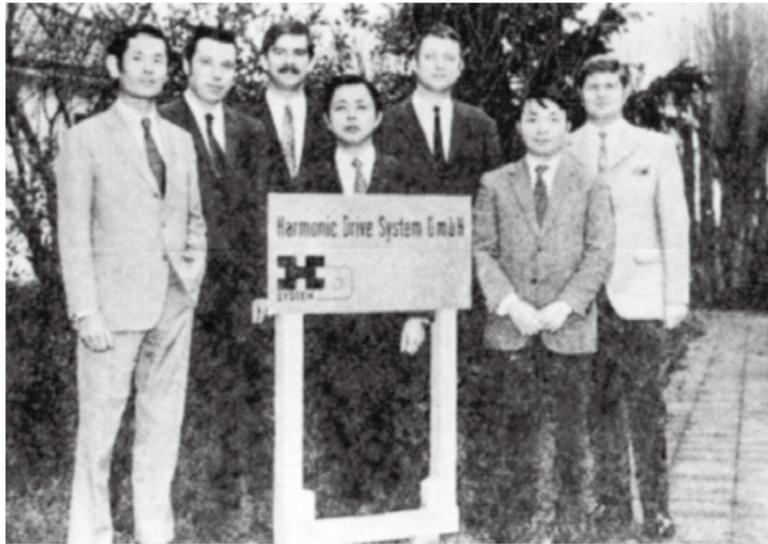
On October 27, 1970, Hasegawa Gear Works established the new company specialized in the production of HarmonicDrive®. On the day before, the inaugural meeting of Harmonic Drive Systems Inc. (hereafter called HDSI) was held with the parties concerned at the Head Office of Hasegawa Gear Works, formally isolating it and making it independent from Hasegawa Gear Works. In the meeting, Kiichiro Hasegawa was appointed as the first president of HDSI (concurrently serving as vice president of Hasegawa Gear Works), Ryuichi Fujii, Hiroshi Kameda, and Atsuo Tokoro were appointed as directors, and Toshio Toi was appointed as auditor.

#### The Origin of the Anniversary of the Founding

The anniversary of the founding of the company was determined as November 10, 1964, when the technology introduction agreement for manufacturing, use, and sales (including import) of HarmonicDrive® in Japan was approved by the Foreign Investment Council, which marks the starting point of the company. This was based on the opinion of Kiichiro Hasegawa.

Generally, the anniversary of the founding of a company refers to the day it was incorporated and registered. It was October 27, 1970 when the Harmonic Drive Division of Hasegawa Gear Works spun off as a subsidiary and was established as Harmonic Drive Systems Inc. Also, it was December 11 of that year when the Foreign Investment Council formally approved USM's application to acquire the shares of Harmonic Drive Systems Inc., making it a joint venture. However, the anniversary of the founding of the company was determined as November 10 regardless.

This was the most memorable day when the HarmonicDrive® mechanism started on its path to numerous possibilities. Kiichiro Hasegawa selected November 10 as the anniversary of the founding with positive intent.



Harmonic Drive System GmbH (front row, from left to right: Tokoro, Hasegawa, and Ito)

At the general shareholders' meeting of HDSI held on November 5, about 10 days later, a transfer of assets was decided. It was decided that HDSI would receive assets worth 350 million yen, including the goodwill of HarmonicDrive®, machinery and equipment, tools, furniture and fixtures, vehicles, products in process, and warehouse stock products from Hasegawa Gear Works. In the same month, HDSI signed an agency agreement for the products with Mitsui & Co., Ltd. HDSI took the first step

as a manufacturer of HarmonicDrive® in both name and reality.

#### Conversion to a Joint Venture and Three Global Locations

USM's application to acquire the shares of HDSI under deliberation by the Foreign Investment Council was formally approved as "Foreign Investment Act Approval No. 9232" dated December 11. On December 30, the shares were transferred from Hasegawa Gear Works to USM. As a result, HDSI became a joint venture.

HDSI also signed a technical support agreement with each of its parent companies in Japan and the U.S. As a result, HDSI established close relationships with its two parent companies in terms of capital and technology. In February 1971, HDSI held its first general shareholders' meeting as a joint venture. As officers dispatched from USM, Robert A. Seyce was appointed as vice president and representative director, and Paul W. Berton and Joseph Ranger were appointed as directors. Also, Tetsuo Sato was appointed as an auditor. At the same time, HDSI relocated its Head Office from Hasegawa Gear Works in Minami-Rokugo, Ota-ku, Tokyo to 2-3-9 Rop-



Reception area for the party celebrating the founding (January 29, 1971)



Kiichiro Hasegawa giving a speech at the party celebrating the founding (January 29, 1971)



Matsumoto Factory against a backdrop of the Japan Alps (1970)



Matsumoto Factory (1970)

Front entrance of the Matsumoto Factory (1970)



Group photograph of the workers of the Matsumoto Factory (1971)

pongi, Minato-ku, Tokyo.

Concurrently with the establishment of the joint venture, Hasegawa Gear Works and USM were also planning to establish a 50:50 joint venture in West Germany. The intent was to realize their original idea of bringing HarmonicDrive® to the international market. This plan was realized in no time. In November 1970, Harmonic Drive System GmbH was established in Langen near Frankfurt. Its business purpose was sales of HarmonicDrive® produced in both Japan and the U.S. in Europe. After its founding, the company conducted sales activities centering on Europe, with emphasis on technical services. This company eventually contributed to the development of HDSI. The details are described in 2-5.

Kiichiro Hasegawa was appointed as president of the company, and Mitsumasa Ito was appointed as local general manager. Mitsumasa Ito, who was in West Germany and had local business experience, was the best qualified person.

A business framework had finally been established to expand the HarmonicDrive® business in the world's three leading industrial countries based on collaboration between USM in the U.S., HDSI in Japan, and Har-

monic Drive System GmbH in West Germany. On a side note, initially, most of the products sold in Europe were manufactured in Japan.

## 2-2 Purchasing Factory Premises in Toyoshina, Nagano Prefecture

### Specific Preparations for a New Factory

The new factory premises that Hasegawa Gear Works was looking for were found in Toyoshina, Minamiazumi-gun, Nagano (currently Azumino-shi, Nagano). After getting information that a carton factory of appropriate size was offered for sale, Hasegawa Gear Works started to conduct thorough research and examination from production and sales perspectives, including suppliers of primary and secondary materials, outsourcing relationships, workforce, and distribution. Concluding that the site was best suited, the company devised a plan to relocate the factory, and began the process of acquiring the factory premises.

Around that time, Hasegawa Gear Works and USM were negotiating to establish a joint venture. Some companies in the gear industry, having heard of that, were voicing their disagreement due to fears of U.S. capital landing on Japanese soil. As this was before the Foreign

\* Atsuo Tokoro, Director (1970–1973), Executive Director (1973–1976), Vice President (1976–1979), Representative Director, President (1979–1994), Representative Director, Chairperson (1994–1997), Adviser (1997–2002), passed away on April 20, 2015.



Sales Department at the Head Office (1971)



Executives of the Matsumoto Factory (1971)



Drilling a Type 3 house with a radial drilling machine



Gear cutting machine



Interior of the Matsumoto Factory

Investment Council approved the acquisition of the shares of HDSI by USM, Hasegawa Gear Works started the acquisition and relocation plan under the pretext of establishing its Matsumoto Factory (currently the Toyoshina Factory) so as not to rock the boat. After signing an acquisition agreement for the carton factory in August 1970, Hasegawa Gear Works proceeded with the preparations to start operation in December, under the lead of the preparatory committee formed in the same month.

#### Preparations for Setting Up the Matsumoto Factory

One of the unavoidable issues at this point in time was how to persuade the employees who expressed their con-

cerns about being transferred to the Matsumoto Factory, i.e., the new company. Before the establishment of the new company, the management of Hasegawa Gear Works tried to persuade them by negotiating with the labor union regarding working conditions and treatment and holding a series of explanatory meetings. In September 1970, the management and labor reached and signed an agreement on the number of employees to be transferred to the new company and the conditions of the relocation of the factory. Eventually, about 80 employees were transferred from Hasegawa Gear Works to the new company.

After that, Hasegawa Gear Works proceeded with the preparations to start operation of the Matsumoto Factory,

making "completing the relocation in a short period of time without causing any inconvenience to customers" the No. 1 priority. The company also locally hired some employees. In addition, the company started OJT training of the locally hired employees in August of the same year.

A total of about 20 employees, in the first and second groups, visited Hasegawa Gear Works in Tokyo for training. On another front, the company started repair work of the Matsumoto Factory as well as electrical work including power, lighting, and cranes. The company were also building welfare facilities, such as cafeterias, break rooms, locker rooms, and baths, and paving the premises at a rapid pace.

The factory became operational, but a problem arose. There were significant temperature differences partly because it was originally a carton factory. Especially in winter, the temperature dropped to below freezing, and they would cover the machines with plastic sheets and work inside.

## 2-3 Managerial Crises and Streamlining Measures

### First Phase of Streamlining

The Matsumoto Factory started to operate in November 1970. Initially, there were 176 employees. This number and the initial production plan were based on the implementation planning to replace a certain percentage of the forecasted market size of power transmission devices with HarmonicDrive®. However, soon after the start of operation, the factory got into a situation where about half of the employees had nothing to work on.

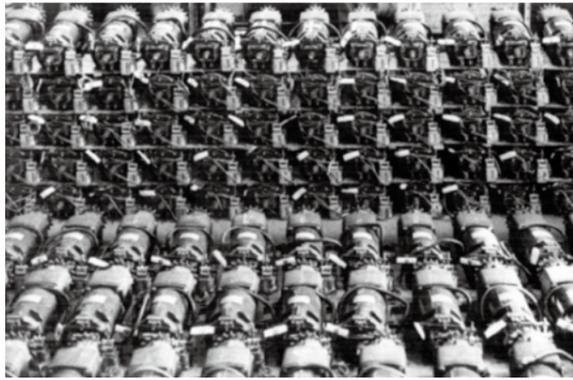
The number one reason was that the business was started on the premise that HarmonicDrive® would replace the existing power transmission devices. As described later in 2-5, the power transmission device market did not provide opportunities to take advantage of the functions and features of HarmonicDrive®, which did not have a very good reputation in the market. It was severely criticized as "something cranky that looks like a tin can" because of its shape.

Unfortunately, the Japanese economy was about to enter an economic slowdown. The Izanagi boom, which

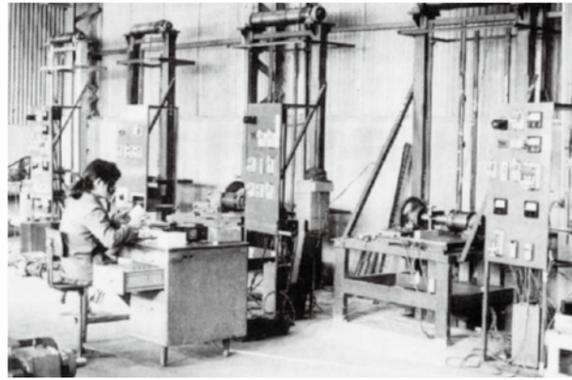


First group of interns from Toyoshina





Actuators for shutters (for Sanwa Shutter Corporation)



Performance testing of the actuators for shutters (for Sanwa Shutter Corporation)

started in November 1965, started to lose its momentum in the second half of 1970. In August 1971, President Nixon's dollar defense policy caused the Nixon shock, pouring salt on the wound. The economic situations in Japan and abroad were gradually affected by sudden changes. HDSI, which was just established, was no exception. It faced a prolonged predicament, such as paying bonuses in installments.

Kiichiro Hasegawa and the executives thought, “We should not put out the fire we worked hard to light” and scrambled for new business opportunities to compensate for the reduced production of HarmonicDrive®. In August 1971, HDSI received an order for the processing of gear couplings from Kyushu Hasec, which had just spun off from Hasegawa Gear Works. HDSI also received an order for the assembly of tape decks from Sankyo Optics Industry in Suwa, Nagano. The company tried to tide over the crisis by taking these orders.

In October of the same year, HDSI conducted a full review of its production lines in case of a long-term decline in incoming orders. The company divided the line, previously producing HarmonicDrive® only, into three lines, from 1st Engineering to 3rd Engineering. 1st

Engineering was used for the preparations of Harmonic Drive®, 2nd Engineering for the assembly and finished products, and 3rd Engineering for operations of the Special Machine Department. The Special Machine Department conducted the processing of gear couplings and the assembly of tape decks as described above, as well as the assembly of coarse and fine adjustment mechanisms for microscopes for orders received from Japan Optical Industries Co., Ltd. (currently Nikon Corporation). HDSI also improved its inventory management system and streamlined the purchase process for main materials.

In November, HDSI relocated its Head Office back to Hasegawa Gear Works in Minami-Rokugo, Otaku, Tokyo to cut down on expenses and streamline the management. The company also integrated purchasing operations at the Tokyo Head Office into the Matsumoto Factory to integrate them into the production system.

In December, in an act of desperation, HDSI decided to dispatch the excess personnel at the Head Office and the factory to the Hitachi Factory of Hitachi, Ltd. and Hasegawa Gear Works. However, many of the employees locally hired in Toyoshina didn't want to be dispatched because “the place of work is too far away,” with 65



“Bullbag”—a product designed for helping a car escape from a rough road or gutter by using its exhaust gas



employees leaving the company voluntarily.

In this month, the number of incoming orders gradually started to recover. In fact, the order volume of 39 million yen in October 1971 increased to 96 million yen in March 1972, an increase of about 2.46 times. However, it did not last long. The order volume took a downturn in April, and drastically decreased to 30 million yen, which was less than the order volume of October of the previous year. The prolonged slump lasted for the rest of 1972.

Unable to see the light, the management kept making desperate efforts to resolve the deadlock. Trying to turn the tide of sales by adopting an aggressive policy, they started to focus on developing new technologies that matched the needs of customers. The products developed in this period include the actuators for lightweight shutters for Sanwa Shutter Corporation, FineJuster® J-16, and valve actuators.

However, these products often failed, resulting in frequent complaints from the customers. In particular, automobile production lines required prompt response and improvement because any interruption of the line due to failure of HarmonicDrive® would cause a significant delay in production.

On another front, HDSI actively worked on implementing human resource-related measures that were drastic for smaller businesses at the time, such as the five-day workweek and the retirement age of 60 (an extension of the retirement age).

In 1973, the year of the first oil crisis, new trends started to arise in the industry. A sharp increase in the percentage of personnel expenses in expenses promoted automation and labor-saving in terms of machinery and equipment. At the same time, industrial nuisances such as noise and vibration were being recognized as social problems. With this situation as a backdrop, HarmonicDrive®, which produced less noise and vibration, was reappraised, resulting in a gradual increase in incoming orders, and the company's business conditions seemed to be on a rising path, which gradually revitalized the company.

### Second Phase of Streamlining

The number of orders for HarmonicDrive® reached a constant level for some time, but it started to be affected by the first oil crisis. The number of orders was on the decrease since the third quarter (October to December) of 1974. In March 1975, it dropped to the record-low

\* Kiichiro Hasegawa: founder, first president, representative director (1970–1976), adviser (2011–2015), and advisory member (2015–2018), passed away on July 5, 2018



Nikkan Kogyo Shimbum dated October 15, 1976



Joseph Ranger, second president (\*1)



Shoji Hata (\*2)



Akira Arakawa (\*3)

level of April 1972. On top of that, Japan's high economic growth came to an end and a period of slow growth started. It became increasingly clear that a quick economic recovery was improbable.

In response to the poor performance of HDSI, USM recommended promptly implementing strong streamlining measures. Driven to take streamlining measures again, HDSI decided to take the second phase of streamlining, giving first priority to the survival of the company with the cooperation of the management and labor.

First, to secure sales at low operation rates, HDSI decided to develop a product called "Bullbag," which was likely to produce sales, although it was out of its domain, and assembled the special sales unit. "Bullbag" was a product designed for helping a car escape from a rough road or gutter by using its exhaust gas. The company conducted sales activities mainly in the Hokushinetsu area, where the severe winter months were approaching.

From July to September 1975, the company made layoffs of a total of 15 days. This was done because the company needed to be recognized as a Specified Depressed Industry of the Employment Insurance Act before applying for the employment adjustment subsidies that the

government provided to support continued employment.

Furthermore, HDSI reformed the organization of the Head Office. Specifically, HDSI transferred a total of 13 employees to Hasec Engineering and other companies to integrate the Engineering and Sales Departments into the Hasegawa Gear Works Group. HDSI also closed the Nagoya Office. As a result, a total of 28 employees left the company, including the ones who left voluntarily.

#### Third Phase of Streamlining

In December 1975, HDSI was finally pushed into a situation where it unwillingly needed to downsize the company. After mature deliberation on all aspects, the company decided to offer voluntary retirement as the third phase of streamlining out of need. In January 1976, HDSI held a series of negotiations with the labor union regarding the conditions. In February, the company held several explanatory meetings for all employees regarding voluntary retirement. At the end of February, the management and labor finally reached an agreement, and 22 employees chose to retire voluntarily.

## 2-4 Becoming a Wholly Owned Subsidiary of USM

### Crisis of Hasegawa Gear Works

While HDSI was looking for a way to independence through various streamlining measures, Hasegawa Gear Works, one of its parent companies, was struggling in a severe business environment. In late May 1976, about three months after HDSI offered voluntary retirement, Hasegawa Gear Works failed to honor promissory notes. Deeply indebted, Hasegawa Gear Works became effectively bankrupt. The social credibility of HDSI, operating as part of the Hasegawa Gear Works Group, was destroyed, throwing the company into the most serious crisis since its founding.

### Becoming a Wholly Owned Subsidiary of USM

As a result of holding an emergency board meeting and discussing how to deal with the emergency, they reached the conclusion that the only way for HDSI to survive was to dissolve the capital ties with Hasegawa Gear Works and go fully under the umbrella of USM. Kiichiro Hasegawa described his feelings at the time in his book *Selling*

#### Dreams:

"If Hasegawa Gear Works went bankrupt with Harmonic Drive Systems Inc., the future of the young company would be in the hands of someone who doesn't know the actual situation."

The management immediately began specific negotiations with USM, and asked the major distributors including Mitsui & Co., Ltd. and correspondent financial institutions for support.

In September of that year, Hasegawa Gear Works reduced its capital contribution of 100 million yen to HDSI, making it a wholly owned subsidiary of USM. At the same time, Kiichiro Hasegawa, who was part of Hasegawa Gear Works, stepped down from post of president. Vice President Joseph Ranger from USM was appointed as the successor president.

It is worth mentioning that Shoji Hata and Hiroshi Kameda put in their own money for the survival of the company and that the business plans and accounting documents prepared by Akira Arakawa (former vice president and representative director) helped the company become a subsidiary of USM.

Under the new organization, the new president, offi-

\*1 Joseph Ranger: director (1971–1976), vice president and representative director (1976), president and representative director (1976–1979), passed away on September 30, 2019.

\*2 Shoji Hata: director (1971–1976), executive director (1976–1984), senior executive director (1984–1991), vice president (1991–1993), auditor (1993–2001), passed away on November 6, 2015.

\*3 Akira Arakawa: director (1979–1984), executive director (1984–1991), senior executive director and representative director (1991–1996), vice president and representative director (1996–1999), passed away on February 2, 2016.



Nobuhiro Naito (\*)

cers, and executives strove to restore credibility lost due to the bankruptcy of Hasegawa Gear Works. First, they visited each of the customers and business partners, including distributors, banks, and raw material suppliers, to explain their circumstances and ask for their help. HDSI could continue its business activities as a result of their commitment to help.

In the board meeting held in September, Atsuo Tokoro was selected as vice president, Shoji Hata was selected as executive director and factory manager, Frank T. Pierce and Steven J. Rifai were appointed as directors, and Tet-suo Sato as auditor, marking a fresh start as the new “Harmonic Drive Systems Inc.” The company also relocated its Head Office to Nishikamata, Ota-ku, Tokyo.

## 2-5 Transition from the Power Transmission Device Market to the Precision Control Market

USM and its Japanese and European subsidiaries had been offering applications of HarmonicDrive® to customers with its use as a power transmission device in mind.

In Japan, HDSI undertook advertising efforts and sales activities inspired by use cases and illustrations in the catalogs of USM. One such example was a booklet

titled *A Collection of Sample Applications* issued from 1967 onwards. HDSI also created a collection of use cases titled *We Are a User, Too*.

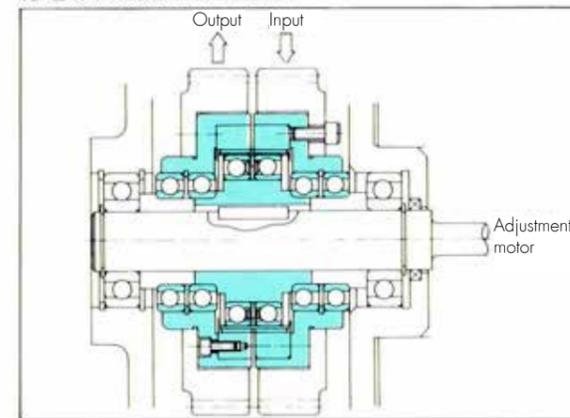
In addition, HDSI once conducted activities to foster understanding of the principles by using the pancake-type plastic HarmonicDrive® developed by USM.

As a result of aggressive promotional activities, the number of use cases started to increase slowly. However, most of the fields did not require the superior technical characteristics of HarmonicDrive® such as low backlash. Only the features other than the technical characteristics, such as compactness, light weight, high reduction ratio, and easy-to-embed components, were appreciated. None of the applications lasted long.

One of the reasons for such a struggle was that the innovative mechanism of HarmonicDrive® was still not well known among engineers and markets that might use it. As it turned out later, the power transmission device market did not provide opportunities to take advantage of the technical characteristics of HarmonicDrive®.

In the early days, HDSI would sell special products developed by USM, such as the electromagnetic strain wave gear RESPONSYN, the phase adjustment unit

An application example of embedding the differential unit FD-O (Multicolor printing machine: Phase adjustment unit)



An application example of embedding in a phase adjustment unit



Phase adjustment unit HarmonicDrive® differential unit developed in 1972

JUST, and the pancake type with high load capacity. Atsuo Tokoro and Hiroshi Kameda worked hard to create new markets by sharing information obtained from USM at technical conferences. However, such applications did not last long nor became a core business at the time.

HDSI later called this period of looking for opportunities “Before Dawn.”

The European subsidiary strengthened the prospect of new applications before the struggling Japanese subsidiary. In Europe, the Transmission Department established as a subsidiary of USM was selling HarmonicDrive® over the years. As with the Japanese counterpart, they were marketing it as a type of speed reducer, but the demand for applications as power transmission devices was low due to the technical characteristics and price of Harmonic Drive®.

While it was anything but their main product, Harmonic Drive System GmbH was established in 1970. Four sales engineers responsible for the sales of HarmonicDrive® were dispatched from the USM branches in Germany, Sweden, and Hungary, who followed the sales policy of USM. In other words, they conducted sales activities targeting power transmission devices, but could

not produce good results, reaching a dead end.

Eventually, Mitsumasa Ito, president of Harmonic Drive System GmbH, decided to change the course of action to find a way out of the current situation.

He decided to build the sales structure around Nobuhiro Naito, a Japanese engineer with extensive knowledge of HarmonicDrive®, and Reinhard Ernst from Germany.

Nobuhiro Naito was a topnotch application engineer and one of the people who was most trusted by Kiichiro Hasegawa. He had an extremely flexible mind and the ability to think freely. He thought outside the box and had never come to a conclusion that something was “technically impossible.” He also had a special talent that allowed him to understand a customer’s nebulous technical idea and make a sketch or a structural drawing of it.

Mitsumasa Ito was mentored by Nobuhiro Naito when he prepared the technical sales materials on Harmonic Drive® while staying in Japan to prepare for the establishment of the German affiliate. Through this experience, he came to the opinion that a person like him was essential to commercialize a product that was not widely known in the world.

\* Nobuhiro Naito: Harmonic Drive System GmbH (1971–1979), Engineering Department (1979–1986), International Department (1986–1992), Marketing Department, Sales Strategy Division (1992–1995), passed away on August 30, 1995.



Industrial robots (manufactured by ASEA (by courtesy of the current ABB))

He then asked Kiichiro Hasegawa to let Nobuhiro Naito reside in Harmonic Drive System GmbH. There were twists and turns because Nobuhiro Naito was also needed in Japan. Eventually, he was transferred to Germany on April 27, 1971.

In Germany at the time, the German language was generally essential for work. Under such circumstances, Nobuhiro Naito quickly learned German well enough to understand technical review requests written in German. As a result, Harmonic Drive System GmbH acquired the ability to promptly give technical answers to customer requests.

Nobuhiro Naito was assisted by Reinhard Ernst, manager of the Materials Department, who was good at drawing out customers' needs. Reinhard Ernst, originally hired as a material manager, had the ability to organize information he learned, including technical data, and explain it coherently.

When Mitsumasa Ito was about to build the sales structure around them, he received the following suggestions from Reinhard Ernst:

**1. Submit a technical article on HarmonicDrive® to professional journals. Place an ad in the journals**

**that carried the article.**

**2. Create a list of technical schools and university mechanical engineering departments and donate a sample of HarmonicDrive® with technical data to use for lectures and experiments.**

Both of the above were important to make Harmonic Drive® widely known among engineers who might use it. Giving top priority to the suggestions, Mitsumasa Ito immediately set them into action. From this point onwards, Reinhard Ernst collected technical data of the customer and passed it on precisely to Nobuhiro Naito, who conducted a technical review based on the information, cast the ideas into shape, and offered them to the customer.

Before long, planting these seeds resulted in a series of diversified applications in Europe. One of the new applications of HarmonicDrive® discovered in Europe during this period was its use by the spinning machinery manufacturer Schlafhorst for the mechanism to apply tension to thread in the spinning machine in the early 1970s. In addition, HarmonicDrive® was used for automatic phase adjustment of the drums of color printing machines. Meanwhile, Mr. Schirlich, a mechanic at a mid-sized printer manufacturer in Germany, made a new suggestion. It was about the produc-

tion of the HarmonicDrive® differential unit he designed, which was specialized for automatic phase adjustment of the drums of color printing machines. The unit was USM's pancake-type component with high load capacity with a casing and four support bearings for easy embedding in the customer's machine. At the time, the pancake-type component was positioned as a power transmission device, which was also considered for robots. Based on the assessment of Nobuhiro Naito that it would fully function, HDSI decided to commercialize it through discussions. HDSI purchased this suggestion for 60,000 Deutsche Marks to produce it as a differential unit for phase adjustment.

There had been applications using one or two cup-type units for spinning machines and printing machines, but HDSI had no series of differential units. While differential-type components had been used for robots, the suggestion focused on phase adjustment units.

The completed series of differential units became widely used by other printing machine manufacturers. Harmonic Drive System GmbH finally got to the starting point as a company.

Around the same time, it started to be used for robots. In 1971, HDSI received an offer from the German company Kleinwächter to use the HarmonicDrive® component for an electrically driven robot. This was a unique opportunity to demonstrate that HarmonicDrive® was suitable for robots.

In the industry at that time, there were already hydraulically actuated industrial robots with complex shapes. HarmonicDrive® manufactured by USM was used for the hydraulically actuated units. Around that time, hydraulic drive systems were being replaced with electric motor drive systems.

Against this background, a sketch drawn by Nobuhiro Naito was sent to HDSI in the period from 1972 to 1973. The sketch depicted an extremely compact prototype industrial robot developed by the German company KUKA. Each of the joints had a HarmonicDrive® unit.

Almost in the same period, the Swedish company ASEA started to develop an electrically driven robot using HarmonicDrive® as part of its joint drive mechanism. This was the moment when HDSI looked at industrial robots based on the information from Nobuhiro Naito. A little later, Japanese robot manufacturers started to develop robots using HarmonicDrive®, sending inquiries to HDSI.

After the prototype robot, HarmonicDrive® was adopted for the mass production robot of ASEA and the French company Renault in 1973. In 1975, it was adopted for the mass production robot of KUKA. These robots set a precedent for the articulated robots currently in use globally.

This is how robot joints started to grow into one of the major applications.

Regarding the background where HarmonicDrive® was adopted in Europe, Mitsumasa Ito said:

“When introducing a new product, the Japanese tend to be reluctant to introduce it unless preceded, focusing on risks rather than performance, whereas the Germans tend to proactively introduce anything good.”

HDSI was greatly inspired by these use cases, such as the mechanism to apply tension to thread in the spinning machine, automatic phase adjustment of the drums of color printing machines, and the joint drive mechanism for robots, because they were completely different from the power transmission devices targeted in the initial production plan. Mitsumasa Ito later said, “This made us think that trying to replace power transmission devices with HarmonicDrive® might not be enough and we needed to look at other markets.”

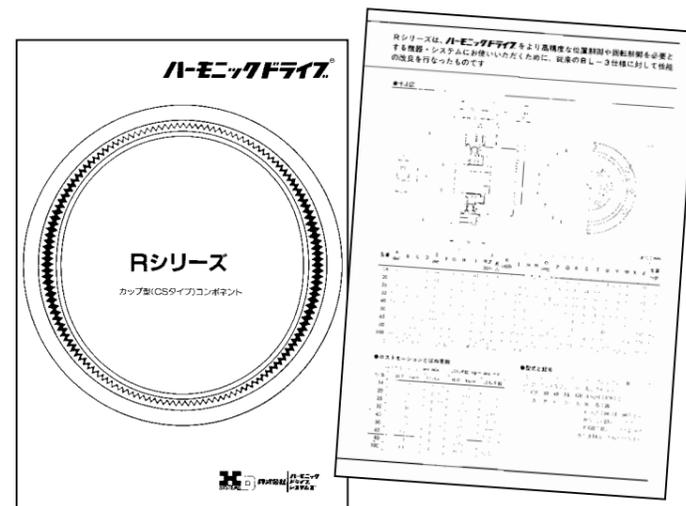
Harmonic Drive System GmbH, starting to develop new markets as a result of meeting customers' needs, became marginally profitable in 1973. In 1974, its business became more stable with a greater profit.

Around that time, Mitsumasa Ito reported the following to Kiichiro Hasegawa:

“Based on the deliveries of the prototypes, the appli-



HarmonicDrive® R series



A catalog of the R series

cations of HarmonicDrive® seem to be in other markets rather than the existing power transmission device market. If that is true, it will take more time until Harmonic Drive® becomes widely known and achieves a profitable sales volume.”

Many years later, a note written by Kiichiro Hasegawa in 1975 was found. It was based on the report by Mitsumasa Ito, saying, “Based on the deliveries of the prototypes, the applications of HarmonicDrive® seem to be in markets other than the existing power transmission device market.”

Eventually, HarmonicDrive® started to be used for the rapid traverse mechanism of machine tools. Mitsumasa Ito called the HarmonicDrive® market the “precision speed reducer market” (currently called the precision control market). This was the moment when new markets clearly opened up.

From this point onwards, HDSI tried to expand the HarmonicDrive® market to the precision control market along with the power transmission market. The company started its actual efforts with meeting specific needs for phase adjustment and tension control in industrial robots and differential mechanisms.

It was the late 1960s when HDSI started to look into the concept of applying HarmonicDrive® to these appli-

cations and build prototypes. USM had already started its efforts, but there were few practical applications in the U.S., Japan, and Europe.

A breakthrough in practical applications occurred when Nobuhiro Naito started to create structural drawings in response to new demand of European customers sent to Harmonic Drive System GmbH. Since then, HDSI frequently exchanged information with Nobuhiro Naito, sending detailed information and preliminary concepts to him.

The engineering team of HDSI created detailed design drawings to meet demand from Europe. The manufacturing floor made efforts to improve its machining capabilities, which also improved its measurement techniques. The entire company started to work together to accumulate the technologies for mass production while working on the assessment testing and prototyping of HarmonicDrive® for precision control.

In the process, there was an incident where no correlation was found between the performance data of a HarmonicDrive® component using the test apparatus of HDSI and the actual performance when it was embedded in a robot. HDSI conducted witnessed tests and technical meetings at the location of the robot manufacturer, as well as comparing data with their engineers visiting the

factory of HDSI. This incident allowed HDSI to improve the performance of HarmonicDrive®, and the robot manufacturer to improve the joints of the robot. The efforts of both parties gradually led to the satisfaction of the required performance.

As just described, the performance of HarmonicDrive® started to gradually improve thanks to the marketing power of Harmonic Drive System GmbH and the technological capabilities and manufacturing technology of HDSI, as well as customer cooperation and advice.

HDSI applied the technologies accumulated in this process to all the HarmonicDrive® products. As a result, HDSI became capable of supplying HarmonicDrive® in other markets in the world, including machine tools and semiconductor manufacturing equipment.

As the applications of HarmonicDrive® expanded in the world, new trends were about to arise in Japan.

At the time, the Japanese-English word “mechatronics”(\*) was created by combining “mechanism” and “electronics.” Automation and labor-saving in equipment, which became prominent after the oil crisis, made further progress in the industry. NC machine tools and machining centers were put into practical use on a full scale. In addition, industrial robots, which used to be introduced on a trial basis for promotional purposes, were now being integrated into actual production lines for practical use. The trend of the times provided a tailwind for the company.

Against this background, HDSI started to receive requests for prototyping robot joints from Japanese robot manufacturers, almost to coincide with the electrification of robots in Europe. HDSI won cooperation from Japanese robot manufacturers as a result of taking the same action as the European subsidiary. In the late 1970s, the needs for HarmonicDrive® components in robots came to the surface.

To seize the opportunity, in November 1977, HDSI started to manufacture and sell the early HarmonicDrive® R series, which was developed for the robot market. HDSI declared its focus on the development of the Harmonic-

Drive® servo actuator product family in its management policy of that year, and organized the Actuator Product Group. The group started to manufacture and sell mechatronics products by positioning HarmonicDrive® as a power transmission mechanism for servo systems.

The Sales Department undertook a marketing strategy based on bold marketing approaches to the industries related to automation and labor-saving facilities.

Trying to create new markets with such a positive attitude expanded the applications and increased sales. For example, the sales in fiscal 1978 increased by 29% year on year, and the sales in fiscal 1979 increased by 32% year on year. HDSI finally recovered from the doldrums that had been going on since immediately after the founding and put itself on track.

Later, as the applications expanded, there emerged many new requests and challenges related to HarmonicDrive®. At the same time, HDSI received a lot of advice from robot manufacturers and end users. HDSI also started to resolve challenges through various efforts, such as achieving higher precision by using vibrational analysis in joint studies with universities.

In the precision speed reducer market, from 2000 onwards, the unit type started to grow significantly as a result of the dramatic development of the conventional cup-type and silk hat-type components and changes in market demands. In terms of the current sales volume, the unit type far exceeds the component type. The background conditions include the establishment of peripheral technologies including cross roller bearings uniquely developed as precision control output bearings as well as lubricants.

The definition and criteria of “precision” change over time as peripheral technologies develop. HDSI has been dealing with the change by improving its machining accuracy and developing peripheral technologies. By sparing no effort, HDSI has been successfully increasing its outlets in the precision control market down to the present day.

\*The word “mechatronics” was coined by Tetsuro Mori, an engineer of YASKAWA Electric Corporation in 1969, and was registered as a trademark of YASKAWA in 1972. Because YASKAWA released the trademark right, it is currently used as a generic term.

# Chapter 3: Expansion

## Expansion of Applications and Organizational Structuring

### 1979–1988

#### 3-1 Birth of a New Harmonic Drive Systems Inc. as a Result of Changes in Capital Relationships

As described in the previous chapter, HDSI saved itself from bankruptcy by becoming a wholly owned subsidiary of USM. However, after a short period of time, USM started to insist on dissolving HDSI. Because it would have too great an impact on the parties involved and HDSI showed strong opposition to it, the dissolution was postponed. In 1976, immediately after that, USM was taken over by Emhart, a manufacturer of glass container manufacturing equipment. At the same time, all the previous management of USM resigned, and it was in no position to dissolve HDSI.

Emhart was friendly to HDSI and gave support implicitly and explicitly. However, Emhart eventually decided to give up the Harmonic Drive business. Around March 1979, HDSI received the following offer from Emhart:

“We are re-evaluating our subsidiaries around the world in terms of restructuring. As part of the effort, we are considering a potential transfer of the Harmonic Drive business. We would like to know if you are interested.”

Emhart seemed to have received an offer from a big

U.S. company that wanted to acquire the Harmonic Drive business.

After serious thought, Atsuo Tokoro, vice president at the time, decided to transition to an independent management structure rather than coming under the umbrella of an unfamiliar U.S. company. With support from financial institutions, HDSI decided to acquire the shares of HDSI owned by Emhart. Immediately after that, HDSI conveyed to Mitsumasa Ito, president of Harmonic Drive System GmbH, the intention to transition to an independent management structure for his approval, and then informed Emhart accordingly.

The idea of HDSI was accepted, paving the way toward independence. In consideration of the future of the Harmonic Drive business and its social credibility, HDSI decided to form a capital alliance with Kodan Electronics Co., Ltd., which had been in a close relationship with HDSI, to let it hold 25% of the shares of HDSI. HDSI also decided to let Harmonic Drive System GmbH hold 50% of the shares to establish closer relations with Europe. The remaining 25% of the shares were held by a separate company established by Atsuo Tokoro with the help of Mitsumasa Ito. The founder of the new share-



USM (in 1940)



Gear Systems Division of USM (in the early 1970s)

holder, Kodan Electronics Co., Ltd., was Yoji Ito, father of Mitsumasa Ito, who was president of Harmonic Drive System GmbH.

Kodan Electronics was a manufacturer specialized in electronics that was established in 1947, and mainly manufactured radars, fish-finding equipment, and fax machines. Although it was in a different type of business, the capital alliance with Kodan Electronics might develop into a joint development project as the applications of HarmonicDrive® were becoming intimately related to electronics. Furthermore, the alliance with Kodan Electronics, which was based on deep human connections and mutual trust, was desirable for the steady development and independent management of HDSI.

At the special general shareholders' meeting held on August 6, HDSI decided on a new management structure. Atsuo Tokoro was appointed as president, Toshiro Kawamoto, executive director of Kodan Electronics Co., Ltd., was appointed as vice president, Shoji Hata was appointed as executive director, and Akira Arakawa and Mitsumasa Ito were appointed as directors. HDSI got off to its third start.

This dissolved all the capital ties with Emhart. How-

ever, the business framework for expanding the sales of HarmonicDrive® globally was maintained. In other words, the collaborative relationships in terms of technology and sales were maintained as before.

#### 3-2 Start of Quality-Oriented Management

##### Announcement of the Three-Year Medium-Term Business Plan (From the 10th Term to the 12th Term) and the Start of Quality-Oriented Management

The year 1980, when HDSI spun off from Emhart and started paving the way toward independence, is called the “First Year of Robots” in Japan.

It might be worth learning about the history of industrial robots. Allegedly, the origin of the word “robot” was *robot* (forced labor) in Czech and *robotnik* (worker) in



New officers (from left to right: Executive Director Hata, Vice President Kawamoto, President Tokoro, and Director Arakawa)



"Kawasaki-Unimate 2000" (by courtesy of Kawasaki Heavy Industries, Ltd.)



"MOTOMAN-L10" (by courtesy of YASKAWA ELECTRIC CORPORATION)



Horizontally articulated robot "SCARA" (by courtesy of Professor Hiroshi Makino, University of Yamanashi)

Slovak. In 1950, the science fiction writer Isaac Asimov published *I, Robot*, inventing the concept that robots were machines that helped humans. Asimov also created the "Three Laws of Robotics": 1. A robot may not injure a human being; 2. A robot must obey the orders given it by human beings; and 3. A robot must protect its own existence.

It was 1962 when robots started appearing in the real world. In the U.S., the industrial robots "Versatran" developed by AMF and "Unimate" developed by Unimation were released.

In 1966, Dr. Engelberger, the father of robotics, visited Japan and gave a lecture on industrial robots, which made industrial robots widely recognized in Japan. The robots of the time used hydraulic servo systems.

As for full-fledged industrial robots, Kawasaki Heavy Industries, Ltd. introduced the technology from Unimation in 1968, and created the first unit of Japan's first domestic industrial robot "Kawasaki-Unimate 2000" (hydraulic servo mechanism) in 1969. Subsequently, Japanese automobile manufacturers started to use industrial robots ahead of other industries.

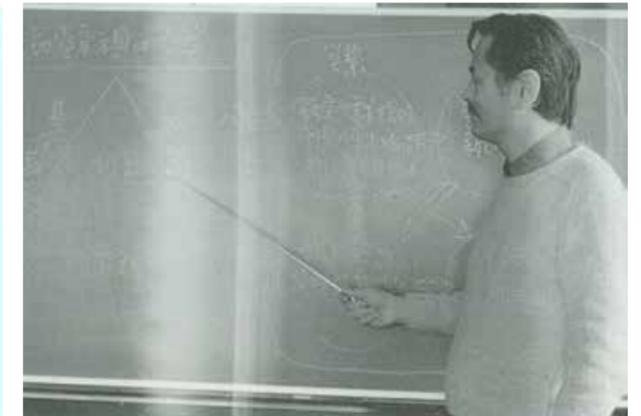
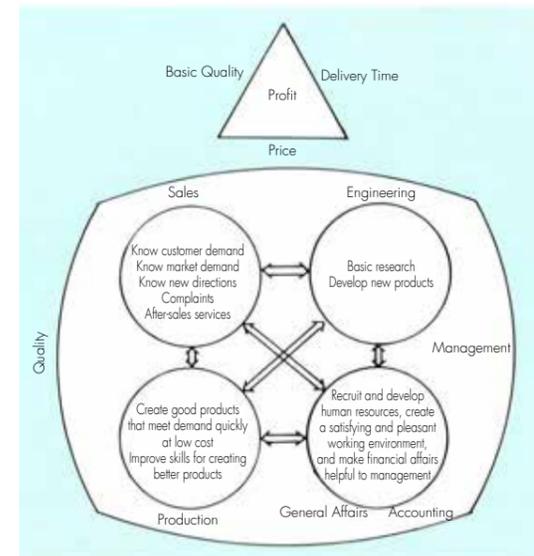
In addition, Japanese industrial robot manufacturers

started pushing forward with research and development. Japan entered the age of industrial robots. In 1977, YASKAWA ELECTRIC developed Japan's first all-electric industrial robot "MOTOMAN-L10." In 1980, Professor Hiroshi Makino, University of Yamanashi, developed the horizontally articulated robot "SCARA." Japanese companies, mainly in the automobile industry, started to develop industrial robots and conduct research on their operations.

On a side note, Japan's robot production value, which was 60 billion yen in 1980, was expected to reach 660 billion yen 10 years later.

At HDSI, the number of incoming orders kept growing rapidly every year since 1980. By 1984, HarmonicDrive® had grown rapidly into near-monopoly status in the market of precision speed reducers embedded into electrically driven robots. HarmonicDrive® was riding the wave of the day.

To deal with the expected rapid increase in incoming orders, HDSI kept recruiting mid-career workers, especially engineers and technicians. To compensate for the deficiency in machining capabilities, HDSI also purchased new equipment such as NC lathes, hobbing machines,



President Tokoro explaining the basic policy of "quality-oriented management" to executives in 1980

and gear shapers, found new suppliers, and negotiated for short delivery times for raw materials. Despite the shortage of floor area, the company was as vibrant as it was at the time of the founding.

In 1979, HDSI introduced the three-year Medium-Term Business Plan starting from the 10th term. In this plan, HDSI set managerial goals for a certain period of time. In the first fiscal year, which was 1979, the company substantially exceeded its performance goals in terms of both sales and profit, getting off to a good start. In April 1980, the year of the 10th anniversary, HDSI launched the second three-year Medium-Term Business Plan as a rolling medium-term business plan.

The basic policy of the plan was "quality-oriented management." One of the critical requirements for a continuously growing company is securing profits. Needless to say, the company needs to have long-selling products. HDSI concluded that, for HarmonicDrive® to be long-selling, its quality had to satisfy customers' needs.

The word "quality" was used in a broad sense, including the price and delivery time of the product as well as the basic performance and quality specific to the product. HDSI aimed to maximize profits by improving three ele-

ments, namely basic quality, delivery time, and cost of the product, based on the previous policy of "giving top priority to quality." Furthermore, the company needed to make its employees aware that not only the Engineering and Production Departments but that the indirect departments including Sales, General Affairs, and Accounting also contributed to the improvement and assurance of product quality. Based on the second three-year Medium-Term Business Plan, each of the departments established its own departmental policy to work on quality-oriented management based on company-wide quality control.

### 3-3 Extension of the Matsumoto Factory (Currently the Toyoshina Factory)

As described in the previous section, the PC market and semiconductor market grew rapidly as Japan entered the age of industrial robots. The applications of HarmonicDrive® expanded further, such as clean robots used in the clean rooms of semiconductor-manufacturing facilities.

However, the sudden increase in orders caused a new problem. It was the absolute shortage of the floor area as a result of increasing personnel and new equipment to enhance production capacity. In 1980, HDSI created the



Ground-breaking ceremony for the first phase of construction in the eastern field of the factory (June 17, 1981)



Workshop concrete flooring of the first phase of construction (July 25, 1981)

“five-year plan for extending the factory” in three phases to cope with an expected increase in orders.

**First phase of construction**

On June 17, 1981, the extension construction was started after the ground-breaking ceremony, and completed on the last day of October of the same year. The floor area was 1,395 m<sup>2</sup>, and the total construction cost was 160 million yen.

The new factory used ALC panels with good insulation for walls and ceilings, and incorporated radiant heating systems using high-pressure steam. It also incorporated displacement ventilation systems using air-conditioning

materials.

All the production equipment including machine tools was transferred on the successive holidays from October 31 to November 1. The factory became operational on November 4.

**Second phase of construction**

In April 1982, the construction to demolish the old factory and build a new factory on the site was started. As the construction was done while dealing with a rapidly increasing number of incoming orders, it was divided into two phases with a dividing line drawn through the center of the old factory. The construction was completed in



First phase of construction: Electrical room and machinery room (front)



Completion of the first phase of construction: Boiler room (front)(October 30, 1981)



Second phase of construction: Disassembly of the assembly shop (May 26, 1982)



Second phase of construction: Construction of the machine shop in two phases (May 30, 1982)



A bird's-eye view after the completion of the first and second phases (November 1982)



Third phase of construction: Construction of the office building (January 1985)



Third phase of construction: Completion of the office building (April 1985)

November of that year, thanks to the close cooperation with the contractor. The floor area was 2,405 m<sup>2</sup>, the total area including the second floor was 3,800 m<sup>2</sup>, and the total construction cost was 217.5 million yen.

**Third phase of construction**

The third phase of construction was intended to improve the production system to cope with the significant growth of the FA equipment business as well as the increased

demand for all products of HDSI. To this end, HDSI decided to demolish the office in the main building of the old factory and build a new main building for office and welfare facilities on the site. The construction was started in October 1984, and completed in the early April 1985. The factory became operational on April 15. On May 25, HDSI held a factory tour and a housewarming party for the office building. On the occasion, the president and executive officers planted a commemorative white birch tree, the



President Tokoro at the 15th anniversary ceremony at Matsumoto Tokyu Inn (May 20, 1985)



First President Kiichiro Hasegawa (right) and Second President Joseph Ranger (left) at Matsumoto Tokyu Inn (May 20, 1985)



Housewarming party with family members invited (at the factory cafeteria) (May 25, 1985)



Housewarming party for the completion of the office building celebrating the 15th anniversary (with family members invited)(May 25, 1985)



Tree-planting ceremony celebrating the completion of the entire construction (first, second, and third phases)(May 25, 1985)

prefectural tree of Nagano Prefecture. It was a two-story SRC building with a total area of 876 m<sup>2</sup>. The total construction cost was 110 million yen.

On the first floor of 428 m<sup>2</sup>, a cafeteria and kitchen as well as the General Affairs, Accounting, and Information Management Departments were placed. On the second floor of 448 m<sup>2</sup>, the president's office, reception office, and the Production Division were placed.

### 3-4 Development and Mass Production of the Special HarmonicDrive® for Volkswagen

One of the highlights in this period was the mass produc-

tion of the special HarmonicDrive® for Volkswagen.

There had been inquiries for supplying HarmonicDrive® to the company since around 1984. This idea was quickly brought into shape in December 1985. HDSI received an inquiry from Harmonic Drive System GmbH for delivering finished products of HarmonicDrive® for robots manufactured in-house by Volkswagen.

The design proposal of Volkswagen showed a radical design where the circular spline and housing were integrated. Conventionally, a separate housing needed to be manufactured to embed HarmonicDrive®, to which Volkswagen made a modification. With no experience in



Mimura (left), Uchikawa (middle), and Koyama (right) visiting Volkswagen



Volkswagen designers visiting HDSI (1988)

manufacturing HarmonicDrive® designed as such, HDSI made company-wide efforts in changing the basic design and developing new sizes including #90 and #58.

The project team consisting of members from the Development, Design, and Production Departments was in charge of the development. Volkswagen requested a lead time of three months, which put HDSI's mobility to the test. In the period from January to February 1986, HDSI presented the drawings for the different sizes to Volkswagen.

However, the process of finding a manufacturing method was full of struggle. For example, Harmonic Drive® had to be embedded into a cast metal casing. According to the design, roller bearings were placed inside the casing, where wear prevention was required. HDSI needed to procure casting materials, look for a processor capable of induction hardening, and look for a polisher capable of polishing hardened surfaces with micrometer precision.

As a result of overcoming these challenges, HDSI made the first delivery in March 1986. These HarmonicDrive® units later served as a design reference when developing the high-precision unit-type FRS series for robots.

There were some failures. Because tooth root cracking was found in a large number of delivered prototypes, Masaru Koyama (quality control), Isao Mimura (circular spline line), and Mitsuru Uchikawa (set line) were dispatched from the Toyoshina Factory to Germany to check and replace about 200 units.

They checked for tooth root cracking with a magnetic crack detector, but struggled when replacing parts that needed to be replaced. After replacing a part, they had to check the meshing to see if it was dimensionally perfect. With no measuring instrument, they worked on the replacement until late at night every day by relying solely on their sense of touch. The products delivered to Volkswagen, about 330 mm in diameter, were heavy, making the work far from easy.

On top of that, Germany was hit by a severe cold wave that winter. The ship laden with the parts arrived late because of the icebound port, which greatly limited the working hours. The warehouse where they worked was extremely cold.

Despite these challenges, HDSI dealt with the complaint in a shorter period of time than they expected. This increased their level of trust in HDSI, resulting in a major



Volkswagen designers visiting HDSI (1988)



A photo with the robot designers of Volkswagen (1988)

order later.

At the end of August 1988, the robot designers of Volkswagen at the time visited HDSI. On the occasion, they asked HDSI to develop a high-torque, low-vibration, low-starting-torque, and easy-to-install HarmonicDrive® to be used for their newly designed robot.

Around that time, the competitors started to make a move in the European market, some of whom made a proposal to Volkswagen advertising low price and ease of installation. Although the engineering team of HDSI found the required performance hard to achieve, HDSI actively proceeded with the development thinking that it was critical to maintain the trusting relationship with Volkswagen.

In February 1989, HDSI submitted new drawings to Volkswagen, and delivered prototypes in July of that year. Subsequently, Volkswagen tested the prototypes. In January 1990, the engineering team of HDSI visited Volkswagen for technical meetings. As a result, Volkswagen submitted the final improvement request. After handling all of the requests, HDSI accomplished the first delivery in June 1990.

To deal with the order from Volkswagen, the produc-

tion floor became extremely busy and staff had to work in three shifts. This greatly contributed to the increase in sales.

On a side note, this experience gave birth to the corporate culture of all staff members across all departments working together in case of an emergency. This idea has come down to the present day.

### 3-5 Establishment of the US Subsidiary HD Systems, Inc.

The sales of HDSI's products in the North American market were handled via the Harmonic Drive Division, which was descended from USM. The types of the HarmonicDrive® products sold were limited due to the indirect sales method. The sales volume accounted for only 1 to 2% of the sales of HDSI.

In the U.S. and Canadian markets, there were opportunities to expand its sales into industries such as semiconductor manufacturing equipment, aerospace instruments, and measuring equipment. HDSI established a policy to directly develop new markets in North America and outpace the competition by boosting engineering services for increasing sales rapidly. HDSI also established a basic



Albert Diamond (right) and Tetsuo Ikuta (left) of HD Systems, Inc.



Tetsuo Ikuta dispatched to HD Systems, Inc. (September 1988)

policy to aim for sales of system products including actuators, although the major products were previously HarmonicDrive® components only.

In February 1987, HDSI established HD Systems, Inc. as a U.S. subsidiary in New York, the United States, and appointed A. Diamond as president. Tetsuo Ikuta from Mitsui & Co., Ltd., who had been working on the sales of HDSI's product over the years, was dispatched to take care of sales and technical services.

In 1988, the office of HD Systems, Inc. was built in Hauppauge on Long Island, approximately 80 km away from Manhattan, New York. The company started to create new markets and provide technical follow-ups, initially with three members including President A. Diamond. In 1991, the workforce increased to five members



Office at Hauppauge, New York (established in November 1987)

with more than a dozen distributors in the U.S., which showed signs of growth.

However, the North American market, 10 times in area compared to Japan, seemed to require a different method for creating new markets. Although considerable difficulties were expected, magazine ads and the efforts of the staff members resulted in about a thousand catalog requests and business inquiries in six months.

In a period of three days from May 9 to 11, 1989, A. Diamond and Atsuo Tokoro, president at the time, visited the Toyoshina Factory. On the occasion, they had thorough technical discussions with Masakatsu Sasahara, deputy general manager of the Development Division at the time, and development staff members. They also exchanged their opinions about the development status and future visions for HarmonicDrive®.

### 3-6 Start of Local Contribution Activities

Almost every year since 1980, the year of the 10th anniversary, HDSI has been holding a classical concert called the "Harmonic Concert" in Toyoshina (currently Azumino-shi), where the factory is located, with a good



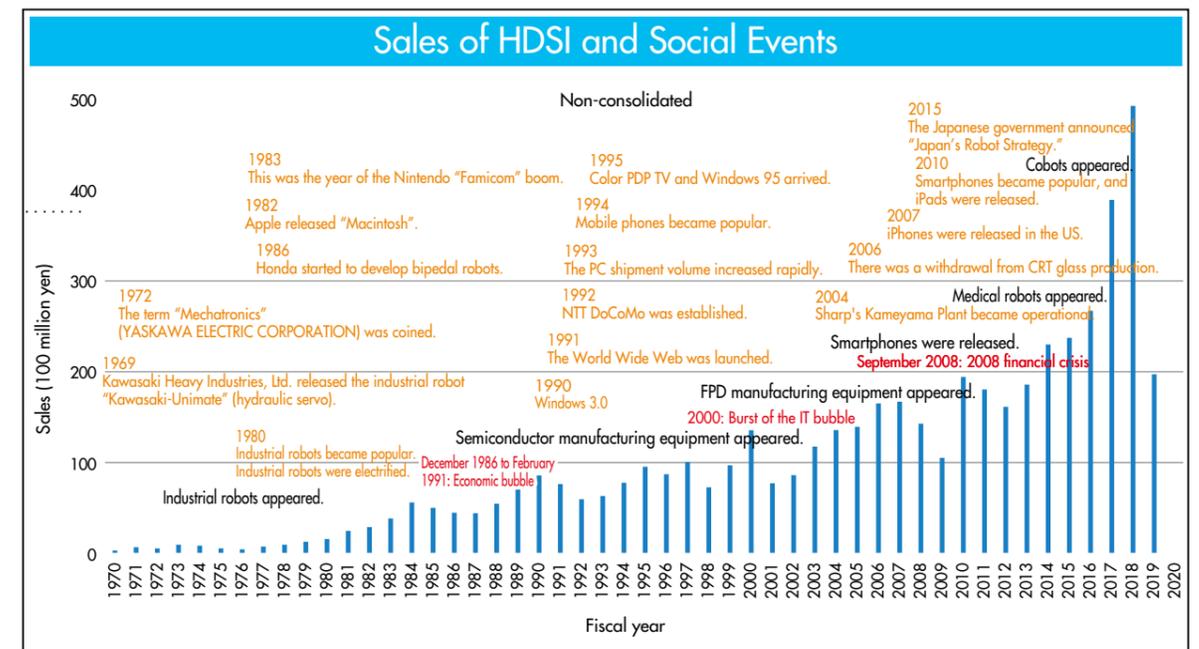
The 10th Harmonic Concert celebrating the 20th anniversary (April 1990)  
 Performers: Mitsuko Shirai (mezzo-soprano), Tabea Zimmermann (viola), Eduard Brunner (clarinet), and Hartmut Höll (piano)

reputation. HDSI started the series of concerts based on our belief that “a company can grow and prosper because of the cooperation and support of the local community. Therefore, it should show gratitude for the local cooperation and support.”

What motivated this event were the managerial crises the company experienced due to the oil crisis immediately after the founding. It was the local residents, employees, and their family members who supported the company. HDSI was looking for an opportunity to show them grat-

itude, which eventually led to holding the concerts.

The concerts up to the third concert were free of charge. From the fourth concert and onwards, tickets were sold for 1000 yen each. All the proceeds were donated to Toyoshina for purchasing books for elementary and middle schools. After the merger of Toyoshina, HDSI started to make donations to Azumino-shi. The concerts have been sponsored by the Harmonic Ito Foundation from the 35th concert held on June 2, 2016 and onwards.



Sales of HDSI and Social Events

# Chapter 4: Independence

## Independence from Foreign Capital and the Beginning of the Hotaka Period

### 1989–1997

#### 4-1 Establishment of New Harmonic Drive Systems Inc.

As described in Chapter 3, HDSI spun off from Emhart in 1979. As the cross ownership of shares with Harmonic Drive System GmbH and other companies became more complex, HDSI ended up encountering a problem in terms of capital. From a long-term perspective, HDSI had to overcome this problem and simplify the shareholder structure to develop innovations on the fly. However, restructuring the shareholder structure would take too much time and effort and be by no means easy. HDSI then decided to establish a new company and transfer its entire business to the company.

On February 23, 1989, HDSI first established a company with the same name, “Harmonic Drive Systems Inc.,” as its wholly owned subsidiary. On March 15, HDSI transferred all of its human and physical assets and liabilities to the new company, including sales transactions, contractual relationships, officers, and employee working conditions and lengths of service. In other words, HDSI created a new company and transferred everything in HDSI to the company with no change.

Later, the former Harmonic Drive Systems Inc., which existed only in name, was taken over by Kodens Electronics Co., Ltd., and temporarily became its wholly owned subsidiary. The new Harmonic Drive Systems Inc. also became a wholly owned subsidiary of Kodens Electronics Co., Ltd. on the same day because it was a wholly owned subsidiary of the former Harmonic Drive Systems Inc. The former Harmonic Drive Systems Inc. was later dissolved.

#### 4-2 Construction of the Hotaka Factory

##### Acquisition of Factory Premises in Maki, Hotaka-Machi

From 1985 onwards, HarmonicDrive® started to be used in ultra-precision instruments in the inspection, measurement, and aerospace industries in addition to industrial robots. As Japan moved into the Heisei era, new applications emerged as a result of a rapid increase in PC shipments, such as clean robots for transferring wafers in semiconductor manufacturing processes and handling robots used in the manufacturing processes of LCD TVs.

Despite the growing expectations for the future with



Grand design of the Hotaka Factory

wider application areas and stable increase in production volume, a concern arose: the factory might become deficient in capacity and production power.

In Toyoshina, where the Toyoshina Factory (formerly called the Matsumoto Factory; renamed the Toyoshina Factory around 1984) was located, urbanization promotion areas and urbanization control areas were specified since the City Planning Act was implemented in 1968. Because the area around the Toyoshina Factory was specified as Category 2 residential district of an urbanization promotion area, use of land was strictly regulated. In these circumstances, the final construction step of the “Five-year plan for extending the Toyoshina Factory” started in 1984. The construction involved demolishing the office and premises a new office building on the site. However, as a result of the construction, the building coverage ratio and floor area ratio of the factory both reached the maximum. This means that no further extension of the factory would be allowed. The site inherently had no ample space, making it difficult to deal with increased production or introduce new businesses. The only option remaining was to build a new factory on a new site. In 1984, HDSI decided to build a new factory.

While HDSI was looking for a site focusing on the former Hotaka, Misato, and Horigane (currently in Azumino City) which were beyond the reach of the regulations, the trend of the times provided a tailwind. Fortunately, Nagano Prefecture established the Nagano Techno Highland Development Organization and was looking for total regional development projects in five areas in the prefecture, which allowed HDSI to collect timely information and find an ideal site.

HDSI singled out a site in Maki, Hotaka-Machi, which had the following conditions:

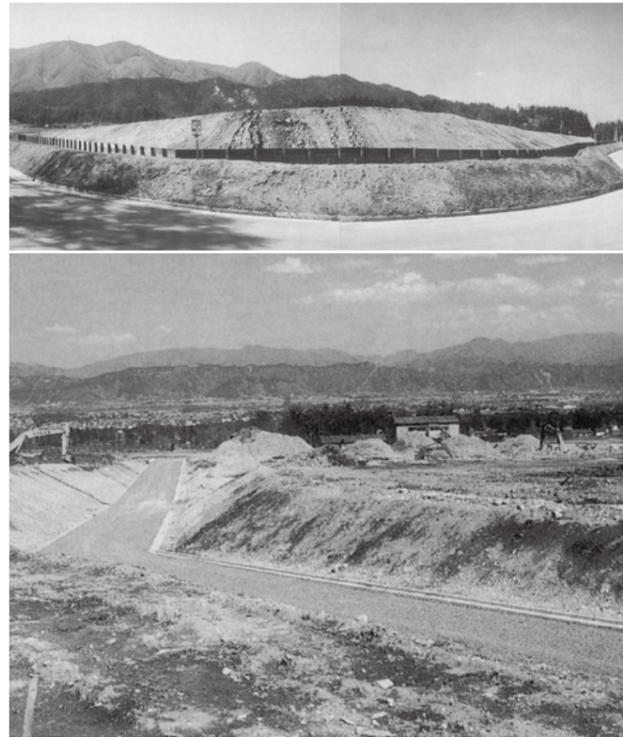
- **The site was about 6 km from the Toyoshina Factory, about 5 km northwest of the Toyoshina Station on the Oito Line, and about 3.5 km west of the Hotaka Station. It was close to Toyoshina and Hotaka, where about 80% of the employees resided, thus allowing for easy commuting.**
- **It was close to neighboring local towns, allowing the factory to recruit workers from a wide area.**
- **It was optimal in terms of connection with the Toyoshina Factory and the conditions related to the product distribution process.**
- **It was about 7 km from the Toyoshina Interchange**



Premises before site preparation, as seen from the front entrance of the current Hotaka Factory



Planned site of about 70,000 km<sup>2</sup> in Oaza Maki, Hotaka-Machi introduced in 1984



Start of construction of the new Hotaka Factory

(currently the Azumino Interchange) on the Nagano Expressway and about 1km from the wide-area agricultural road connecting Matsumoto City and Omachi City, allowing for easy transportation of materials and products.

- Great cooperation from the local community and land owners was expected. In particular, the factory would be able to recruit workers locally.
- The required area could be ensured, and the area was planned to be classified as a quasi-industrial district. A series of facilities (e.g., welfare facilities) could be built, eliminating the need to disperse them and thus improving investment efficiency.
- Electric power of 2,000kW was available, which was sufficient.
- It would provide an excellent working environment.

HDSI decided to acquire the premises because of the optimal conditions. Initially, HDSI was working toward acquiring about the half of the area compared to the cur-

rent area. Senior Executive Director Shoji Hata insisted on purchasing the current area. It took about two years to negotiate with many land owners. In April 1986, HDSI completed all the procedures and officially acquired the premises.

It was a dry field of about 66,544 m<sup>2</sup> at an altitude of 650 to 720 m, gently sloping toward the east. The south side and north side were forested with red pine. It had a grandstand view of Azumino. It was a place of scenic beauty with clean air, providing an excellent working environment as well as sufficient space. Compared to the Toyoshina Factory, the site area was expected to be increased by more than 6 times, buildings by about 1.3 times, welfare facilities by about 1.7 times, and green coverage by more than 13 times.

#### Finalization of the Grand Design of the Factory

Upon the construction of the Hotaka Factory, the future direction was summarized as a grand design. The basic



Start of site preparation work (August 1989)



Preparation of the road on the premises (March 1990)



Ground-breaking ceremony for the construction (March 26, 1990)



August 1990

concepts were as follows:

- The Hotaka Factory should be considered as one of the assets of the company, Hotaka, and Azumino. The first priority should be given to its beauty, so as not to ruin the surrounding landscape or atmosphere.
  - Although the concept above might be somewhat inconsistent with the company's economic efficiency, the company's economic efficiency was temporary, whereas the natural environment (and its beauty) was permanent.
  - Because the factory would be built at the expense of natural forests, the existing trees and forests on the factory premises should be preserved as much as possible.
- Based on the basic concepts above, HDSI decided on the following development policies.
- In principle, the building should be allowed to extend up to the bank with chestnut and walnut trees on the front side (east side), and should not extend further toward the front.
  - In principle, extension shall be toward the west side (mountain side).
  - The buildings shall be examined in terms of height,

width, and color so that they are in harmony with nature. In principle, the height of the factory shall be limited to the height of the current factory, unless it did not ruin the harmony with the whole when seen from the front side. The width should be within the widths of the roadways (north and south) on the factory premises. The color should not clash with the natural environment. Primary colors should be avoided.

- When constructing buildings on the southeast area on the front side (formerly the field and currently TRIAD), the buildings and their layout should be determined by taking into account the beauty of the entire factory so that they would symbolize HDSI. The buildings should be balanced and in harmony with the slope of the site as well as the height and colors of the buildings (nothing should be decided based on a layman's view).

Taking into account these conditions, HDSI tried to make the entire Hotaka Factory symbolize Azumino.



Unearthing of pot-shaped earthenware with two handles at the archaeological site of Shinbayashi (by courtesy of the Azumino City Board of Education)



Paving stones at the archaeological site of Shinbayashi (as seen from the south-west) (by courtesy of the Azumino City Board of Education)



Pot-shaped earthenware with two handles unearthed from the archaeological site of Shinbayashi (by courtesy of the Azumino City Board of Education)



Stone tools unearthed from the archaeological site of Shinbayashi (by courtesy of the Azumino City Board of Education)

#### Unearthing of the Archaeological Site of Shinbayashi and its Preservation by Earth Filling

After HDSI acquired the premises and applied for development permission, an unexpected problem occurred. The company was informed that there was an archaeological site. HDSI immediately held discussions with the Culture Division of the Nagano Prefectural Board of Education and the Archaeological Site Preservation Council of the Hotaka-Machi Board of Education. Later, HDSI requested a trial excavation of the site, notifying them of its intention: "If it is truly valuable, it should be passed down to the generations as a shared heritage of the nation. We will fully cooperate as a company." The excavation began in March 1988.

The site was later named the "archaeological site of Shinbayashi."

The excavation covered a total extension of about 3,500m. Digging trenches of 1 m in width and about 15cm in average depth (i.e., the thickness of black soil to the loamy layer) revealed the following:

- **All of the features were from the early to late Jomon**

#### Period.

- **It was believed that more dwellings might exist in the area where eight dwellings were found as a result of trenching. The features had been partially damaged during cultivation because of the shallow feature surface. Earthenware was scattered all over the site. Because of the high density of the features, it would be desirable to preserve the site by earth filling.**
- **The density of the features was low in the area where three dwellings were found as a result of trenching. The features had been scraped during cultivation and mostly damaged. It would be necessary to preserve the south side by earth filling.**
- **Almost no earthenware was found. It posed no problem to the development.**
- **It would be desirable to preserve the area that had been severely damaged by cultivation by earth filling although only a small number of earthenware items were unearthed.**

After reviewing these conditions, it was ultimately determined to preserve it by earth filling.



Completion on November 21, 1990



Entrance (November 1990)



General affairs/accounting floor



Lobby floor



First floor before equipment was brought in

#### First-Phase Construction Plan, Basic Design, Start of the Construction, and Pillar-Setting Ceremony

After a slight delay caused by re-applying for development permission due to the buried cultural property, HDSI started working on the design process in October 1989.

When creating the site plan for the new factory, emphasis was placed on the following two aspects. First, the plan should fully take into account a margin for business expansion while looking to the 21st century. Second, it should aim to be a "green factory," a factory with high green coverage built in an area with a wonderful natural environment that was unimaginable in a large city. In addition, welfare facilities for employees and contribution to society were included as important policies.

As the full-scale site preparation work started at the end of 1989, HDSI entrusted the Nagoya branch of the architectural design office RIA to create specific plans for the first-phase construction plan.

In terms of the scale of the construction, the total area of the factory building was 6,780 m<sup>2</sup> with a machinery room/welfare building of 350 m<sup>2</sup>. The factory building had a full two-story structure of 90 m north to south and 36m east to west for effective utilization of the factory premises in the 21st century. To deal with future expansions according to the company's growth, the conception drawing assumed the second phase and third phase of construction to be on the west side.

After the ground-breaking ceremony held on March 26, 1990, the construction was carried out by a consortium of TAISEI CORPORATION and NOGUCHIGUMI CO., LTD. Favored by good weather, the construction proceeded smoothly. After the pillar-setting ceremony held on June 20, the construction was completed on November 21.

On May 23, 1991, HDSI held a housewarming party for the completion of the Hotaka Factory at Tokyu Inn in Matsumoto City. On May 23 and 24, HDSI held the



President Tokoro giving a speech at the housewarming party for the completion of the Hotaka Factory



Commemorative tree celebrating the completion of the Hotaka Factory  
Zelkova serrata (Japanese zelkova) from the national distributors of Mitsui & Co., Ltd. and Rhododendron obtusum (Japanese evergreen azalea) from the HDS Cooperating Association



Commemorative tree celebrating the completion of the Hotaka Factory  
Tilia maximowicziana (Maximowicz's lime) from Harmonic Drive Deutschland (as of 1991)



Full-grown Tilia maximowicziana (Maximowicz's lime)  
(photographed in 2017)



Inscription on the plate of Tilia maximowicziana (Maximowicz's lime)

IN LANGJÄHRIGER FREUNDSCHAFT  
HARMONIC DRIVE DEUTSCHLAND  
MAY 1991  
長年の友好関係を記念して  
ドイツ・ハーモニクス・ドライブ  
1991年5月

Harmonic Drive International Symposium celebrating the 20th anniversary at Azumino Hotaka View Hotel, as well as a factory tour of the Hotaka Factory. The new Hotaka Factory started to operate with the hopes of many people.

**Launching of the Toyoshina Factory Anew as the Research and Development Center**

The General Affairs, Accounting, Information Management, and Production Departments were transferred from the Toyoshina Factory to the Hotaka Factory. The Development Division remained at the Toyoshina Factory to serve as a development center. In December 1990, HDSI launched the new "Toyoshina Research and Development Center," which was later used by the Development Division and the FPS (fine positioning system) project.

The configuration of the Toyoshina Research and Development Center was as follows:

- **Building previously used by the Development Division: The second floor became the office for the Speed Reducer Development Department. The first floor was used by the Mechatronics Development Department as the laboratory.**

- **Old office building: The old general affairs/accounting room on the first floor was remodeled into a medium-sized meeting room accommodating up to 50 people. The second floor was used by the Mechatronics Development Department, Development Promotion Department, and the FPS project.**
- **Factory: Used as the laboratory of the Speed Reducer Development Department and the office of the Prototype Development Department. In actuality, it only contained some prototyping machines in certain locations, and was used as a space for playing table tennis and badminton during break time.**

**Relocation of the Toyoshina Research and Development Center to the Hotaka Factory**

HDSI later decided to integrate the Toyoshina Research and Development Center into the Hotaka Factory. From October 7 to 11, 1993, HDSI transferred the Development, Second HD Production, HP (planetary speed reducer), and Prototyping Departments of the Toyoshina Factory as well as the Kohshin Office, and changed the layout of the Hotaka Factory. It was the first full-scale layout change since moving to the completed Hotaka Fac-



A bird's-eye view of the Hotaka Factory



Completion of the new office building of the Hotaka Factory on April 1, 1996



Entrance of the new office building



First floor of the new office building

tory in December 1990. The endurance test laboratory, which had been under construction, was completed, and HDSI held a completion ceremony on November 15. All the related departments had been transferred by the end of November of the year.

#### Party to Celebrate the Completion of the Extension of the Hotaka Factory Building

Soon after the integration into the Hotaka Factory, the factory needed an extension. There were an increasing number of orders for the HP/CP series manufactured by the Manufacturing Department, and the number was expected to increase until 1997, calling for an extension. After the ground-breaking ceremony held on May 18, 1994, the construction was completed and HDSI held a party to celebrate the completion on October 25.

On the first floor, an area of 1,713.78 m<sup>2</sup>, about half of the existing floor area, was added to the west side. An area of 197.1 m<sup>2</sup> was added to the second floor, totaling 1,910.88 m<sup>2</sup>. This increase in area was equivalent to about 25% of the existing floor area. In addition, break rooms were built as welfare facilities. Hand-washing sinks, which had previously been only at the south and north ends,

were built in the middle of the first floor for the greater convenience of employees.

Furthermore, the following were taken into account with regard to the extension:

- (1) **The numbers of pillars and pits were minimized.**
- (2) **The paint booth and the assembly station for RE (reducers, etc.) products were moved to the first floor close to the shipping area.**
- (3) **The warehouses for RD products (Harmonic products) and HP (planetary speed reducers) were moved to the first floor to directly connect the production lines and warehouses.**
- (4) **The layout of the mechatronics laboratory and production was changed accordingly.**
- (5) **The operations departments and production lines were laid out such that they were directly connected.**

#### Completion of the New Office Building of the Hotaka Factory

HDSI also proceeded with the improvement of the office building. The construction was started in 1995, and completed at the end of March 1996 when spring finally came to Azumino. On April 1, HDSI held a completion

ceremony with President Mitsumasa Ito, the successor to Atsuo Tokoro, and other parties involved. On April 26, HDSI held a factory tour of the factory for local residents and the Cooperating Association. HDSI also held a housewarming party for the office building.

#### Metal Sculpture SCREEN-CANYON at the Hotaka Factory

In the early June 1996, the metal sculpture titled “SCREEN-CANYON” (1983) created by the sculptor Yoshikuni Iida (1923–2006) was placed at the entrance lobby of the new office building. The work was large in size, 3.2 m in height, 6.4 m in width, and 1.5 m in depth. This work was displayed on loan by courtesy of Yoshikuni Iida.

Displaying a work of Yoshikuni Iida, who had a strong will and acute sensitivity for creation, in the company meant a great deal. President Mitsumasa Ito believed that, to work on a product or develop future technology based on new ideas, an engineer needed a passion for manufacturing, a strong will, and sensitivity for generating creative ideas. He expected that the employees involved in technical development would improve their imaginative

power by appreciating the work every day.

“SCREEN-CANYON” is currently displayed at TRIAD IIDA-KAN.

## Our Ties with Yoshikuni Iida and His Achievements



Yoshikuni Iida

### Motivation for Displaying “SCREEN-CANYON”

What motivated HDSI to display “SCREEN-CANYON” at the Hotaka Factory was a 30-plus-year friendship between Yoshikuni Iida and Mitsumasa Ito since they first met in Germany. Mitsumasa Ito treated Yoshikuni Iida as a mentor sometimes, and as a respected friend at other times. In the spring of 1996, Mitsumasa Ito, president at the time, was enjoying wine with Yoshikuni Iida. They talked about the exhibition “Yoshikuni IIDA—in the Time and Space of Existence and Words” held in Mie, Tokyo, and Kyoto in 1988. Mitsumasa Ito told him that “SCREEN-CANYON” he saw at the National Museum of Modern Art, Kyoto was so impressive that it was still etched in his memory. Hoping to see it again, Mitsumasa Ito asked about its whereabouts. Yoshikuni Iida said that the sculpture was sitting in a warehouse because the construction of the building planned to accommodate the sculpture had been halted. Thinking that it was worth more than sitting in a warehouse, Mitsumasa Ito proposed displaying it on loan at the Hotaka Factory. Yoshikuni Iida readily agreed. Today, there is an art gallery called “TRIAD IIDA-KAN” on the premises of the Hotaka Factory. It was constructed to display “SCREEN-CANYON” as agreed upon then.

### The Character of Yoshikuni Iida

Yoshikuni Iida is certainly one of the world’s leading sculp-

tors. After majoring in the arts at Keio University Faculty of Letters, he studied at the Oil Painting Department of Tokyo University of the Arts. He studied under Ryuzaburo Umehara (1888–1986) and started his career as a painter. He worked vigorously and became a hopeful up-and-coming painter. As a result of studying in Italy, Austria, and Germany, he made a career change to become a sculptor, ending up being highly acclaimed and successful.

In 1963, he exhibited “Hito” at the sculpture symposium “Forma Viva” held in Yugoslavia as the representative of Austria. In the same year, he also participated in the Symposium of European Sculptors held in Berlin. He created a large marble sculpture displayed in front of the parliament building. His works were later displayed at various locations, including Vienna, the Berlin Fire Department, and the Outdoor Sculpture Museum along the banks of the Seine in Paris.

His works were also displayed at various locations in Japan, including Namegawa Island, Shinjuku Nomura Building, Tokyo Metropolitan Gymnasium in Sendagaya, Suntory Hall in Roppongi, Keio University Mita Library, the venue of “Expo ’70,” the fountain in front of Shin-Maebashi Station, a square in Senri New Town, Tochigi Prefectural Museum of Fine Arts, the Utsukushi-ga-hara Open-Air Museum, Isezaki Shopping Street in Yokohama, Kure Municipal Museum of Art, Kobe Portopia, Hokkaido Museum of Modern Art, Sapporo Art Park, and the Hakone Open-Air Museum.

### A Multifaceted Person

At the time when HDSI displayed his work on loan, Yoshikuni Iida started to be recognized again as a painter. His oil paintings were displayed at museums in Cambridgeshire, England,



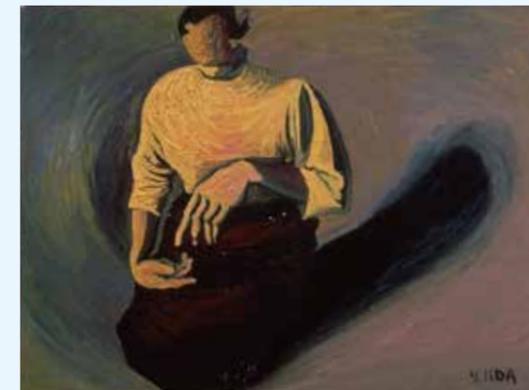
“SCREEN-CANYON”

Tokyo, and Tochigi. Yoshikuni Iida was a multifaceted person. He was renowned as a poet and essayist and wrote classics. His published works include poetry books such as *Nancy’s Armor*, *May of Discs*, and *In a Unknown Town*, and collections of essays such as *Invisible Sculpture*, *Vibrating Space*, and *The Idea of Sculpture*. *Picasso*, published as a title in the 20th Century Thinker Library of Iwanami Shoten, and *The Sculptor, Starting on the Path to Creation*, published as a title by Iwanami Shinsho, were highly acclaimed as classics. The writings of Yoshikuni Iida were once used in high school textbooks on the Japanese language. Yaeko Nogami (1885–1985), a novel-

ist, wrote about Yoshikuni Iida in the postscripts of her collection of essays *Ichiju no Kage* and her major work *Meiro*. In July 1997, he wrote serial articles in “My Resume” in the Nihon Keizai Shimbun.

He was also talented as an actor. In his days in Vienna, at someone’s suggestion, he played the leading role in a play that became a great hit and had a long run. In Japan, the film director Hiroshi Teshigahara offered him a role in *Rikyu* (1989), but he declined. He made a cameo appearance as a court physician of Hideyoshi Toyotomi.

He passed away in 2006 at the age of 82.



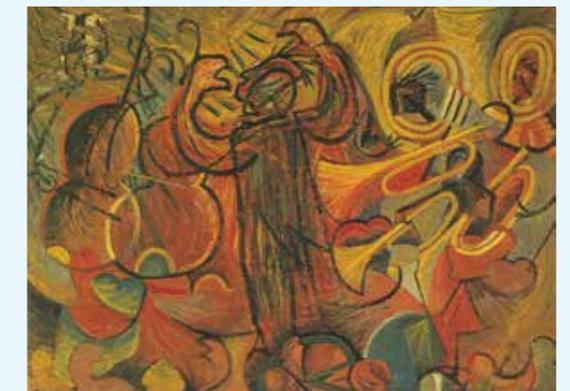
“A Woman Sitting on the Floor,” 1955, oil on canvas



“Untitled (Cosmic Nude),” 1959, oil on canvas



“Sculpture Fountain / Seesaw” (Rainbow and Water Square at Serigaya Park, Machida), 1989, stainless steel



“Orchestra of Two Hands,” 1953, oil on canvas



Establishment of the Cooperating Association. Shozo Tomioka, director, general manager of Production Division, and advisor of the Cooperating Association, giving a speech



Establishment of the HDS Cooperating Association (June 29, 1990)



Convivial meeting of the HDS Cooperating Association



Hiroshi Momose, president of Unicon, chairman of the HDS Cooperating Association

### 4-3 Establishment of the HDS Cooperating Association

Today, the companies in the HDS Cooperating Association are indispensable to the production activities of HDSI. The HDS Cooperating Association was established in 1990.

At the New Year greeting meeting, Hiroshi Momose, president of Unicon, made a proposal to establish a cooperating association. What motivated him to make this proposal was that the general manager of the Production Division of HDSI suggested creating an organization for training as a way of resolving problems such as late deliveries and defects.

Apparently, the affiliated companies were struggling to satisfy the precision requirements of HDSI. In an interview conducted for compiling the company's history, President Hiroshi Momose said the following.

“We could not find the cause of defects, and were trying to figure out how to manufacture conforming parts. When we measured manufactured parts immediately after, they were conforming. A deviation of 5  $\mu\text{m}$  or 10  $\mu\text{m}$  was acceptable for other companies, but a deviation

of 2  $\mu\text{m}$  in one night would be considered defective for HarmonicDrive®. That was the level of precision we were required to achieve.”

Aside from training, it was important that everyone involved with HarmonicDrive® should be on the same track. The affiliated companies believed that they needed to set up a forum where they could communicate with each other on a regular basis.

For HDSI, which had been developing thanks to the cooperation and support of the affiliated companies, the proposal to establish the Cooperating Association was a heaven-sent opportunity. After HDSI gave willing consent, 13 founders and others spent six months in preparation for the establishment. They had several meetings to create proposed bylaws and organization. On June 12, they had a preparatory meeting for the establishment. On June 29, they had an inaugural meeting at the Isamiya-Kaikan Hall in Toyoshina. The number of member companies at the time was 50. Hiroshi Momose, president of Unicon, was appointed as chairman, and Terumi Shimizu, executive director of Toshin Specialty Steel, was appointed as vice chairman.

The membership was diverse, including individuals responsible for machining who worked for HDSI, as well



ISO 9001 certification audit

as material and member manufacturers with staff sizes several times that of HDSI. Most of the company had a close relationship with HDSI, many of which had helped HDSI overcome countless crises and challenges since its founding.

The Association was organized into six groups (namely the Material Group, Heat Treatment Group, Bearing Group, Jigs and Tools Group, Machining Group, and Electric Equipment Group) and started operations. HDSI promised to keep making its best efforts to create attractive products, services, environments, and trading relations to satisfy the HDS Cooperating Association as well as customers and parties involved.

### 4-4 Acquisition of ISO 9001:1994 Certification

#### Establishment of the Quality Assurance Promotion Office and Departmental Quality Assurance Department

HDSI had been conducting quality assurance activities by using TQC (total quality control) techniques. However, HDSI could not produce satisfactory results, partially because the conventional TQC had no clear requirements

or criteria.

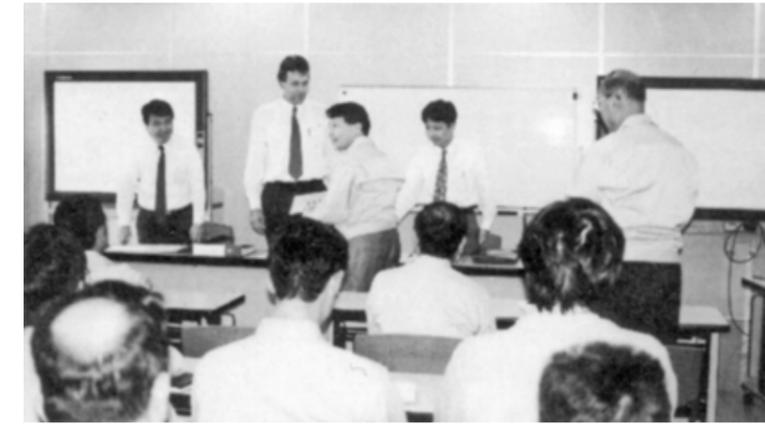
While HDSI started finding limitations to quality assurance based on TQC, there were an increasing number of companies acquiring ISO 9001:1994 certification, the international standard for quality systems.

ISO 9001:1994 is not a standard that certifies the quality of products and parts for customers. It certifies that quality systems are in place for customers. Therefore, it covers all the processes from orders to after-sales services. One of the characteristics is that it clearly defines requirements for all departments and processes related to quality, in addition to the management. It also defines document control procedures, which the Japanese are generally not good at. In other words, the procedures do not tolerate ambiguity, one of the characteristics of the Japanese. The standard was most appropriate for HDSI, which started expanding globally.

Other quality-related awards included the Japan Quality Control Award and the Deming Prize. These awards did not require ongoing auditing once they were awarded. On the other hand, ISO 9001:1994 required periodic audits, and poor results would lead to a loss of certification. HDSI considered the introduction of ISO



Jiro Chiba, executive director



Granting of the certificate

9001:1994, believing that it would allow for true quality assurance.

In fiscal 1993, HDSI decided to acquire certification under the leadership of Executive Director Jiro Chiba. The medium-term business plan at the time included the "quality assurance activity policy" as one of the priority policies, stating that each employee should put him or herself in the position of the customer and provide quality products that would win their trust and satisfaction. As a way to actively promote such activities, HDSI decided to be reviewed for ISO 9001:1994 at the executive directors' meeting held in February 1993.

#### Start of the Certification Activities

In April 1993, soon after deciding to be reviewed for ISO 9001:1994, HDSI established the Promotion Office. The roles of the Office included learning the promotion method and instilling a basic understanding of the ISO within the company.

They started their activities by looking for an ISO certifying body and investigating the overview of the ISO. As a certifying body, HDSI selected TÜV Rheinland Japan Ltd. (hereafter called the TÜV), the Japanese subsidiary of TÜV Rheinland Group headquartered in Germany. Although there were a number of certifying bodies in

Japan, HDSI purposely selected a Germany-based certifying body that wouldn't offer great flexibility.

In May, HDSI held an ISO explanatory meeting with the managers at the Head Office and factories. On May 20, HDSI also held the first committee meeting comprising the general managers and overall managers.

For ISO certification, the president and all the other employees were required to be involved in every aspect based on the quality systems determined by HDSI. At the committee meeting, the committee members from each division examined the promotion method, activity plans, and in-house training so that all the divisions could start their activities simultaneously based on a common understanding. Since then, HDSI went through the steps below under the direction of the committee:

- (1) **Sorted out all the rules and regulations in the company and checked the interrelationships (parent-child relationships) with each other.**
- (2) **Checked each of the rules and regulations above against the ISO requirements to determine its necessity, excess, or deficiency. Appointed a person in charge of each of the requirements (20 items in ISO 9001:1994), and formed working groups to start the operation.**
- (3) **Completed a system of the rules and regula-**

**tions above by creating a proposed quality manual according to the ISO based on the quality systems of the company.**

- (4) **Divided the committee into two teams due to location constraints and the degrees of the ISO requirements.**

**At the Hotaka Factory, the person in charge of ISO certification from Nichicon Corporation, which had already acquired ISO certification for each factory, gave a speech to HDSI's managers about their experience on June 11.**

**At the Head Office, HDSI held an explanatory meeting titled "Training for ISO Certification" by Komatsu Career Create for the relevant employees of the Head Office including the manager on July 16.**

- (5) **Developed internal auditors via external training to conduct internal audits required by the ISO.**

- (6) **Conducted an internal quality audit at each of the departments from May to June 1994.**

In November 1994, the certifying body TÜV conducted a preliminary survey. HDSI completed all the rules and regulations including manuals by December. Starting in January 1995, to eliminate any discrepancy between the rules and regulations and actual operations,

HDSI performed actual operations according to the rules and regulations and made necessary modifications accordingly.

HDSI underwent a final review in the fall of 1995. First, the Tokyo Office was reviewed on October 13, and the Hotaka Factory and all the departments were reviewed from October 18 to 20. As a result, HDSI passed the review with astounding results of zero defects and acquired certification. The company accomplished this splendid feat in about two years and eight months after deciding to acquire certification. One of the auditors of TÜV paid a compliment to HDSI, saying, "There have not been very many companies that devoted this much time to certification. The results were extraordinary."

HDSI devoted time to certification for a reason. HDSI was aware of many companies in Japan that acquired certification in one year or less, and that many of them struggled afterward. HDSI believed that, in most cases, the manuals and rules they created did not fully reflect their on-site operations. To prevent this from occurring, HDSI built a system with all the relevant departments involved. HDSI also focused on making improvements while implementing the system. Doing this required about two and a half years.

However, acquisition was not an end goal. It was just



ISO 9001 certificate

the foundation for quality assurance activities. After acquisition, HDSI's priority was given to company-wide efforts to maintain and improve the quality systems and achieve even higher levels.

#### ISO 9001:2000

In 2002, ISO 9001:1994 was revised to ISO 9001:2000. Whereas the previous standard required a quality assurance system, ISO 9001:2000 required a quality management system, where the company was required to make continual improvements by identifying processes to control and implementing the PDCA (plan-do-check-act) cycle.

From October 16 to 18, 2002, TÜV conducted an external audit for ISO 9001:2000. As a result, HDSI achieved zero defects.

### 4-5 Launch of the HartMax (HM) Project

#### Start of Basic Design and Detailed Design

At the end of 1995, HDSI decided to establish a LAN (local area network) along with the construction of the office building of the Hotaka Factory. The creation of a network environment and its active utilization would promote data sharing across the company and more effec-

tive use of the equipment. It would also provide flexibility and help to promptly address various requests from customers.

Against this background, HDSI launched the “HartMax (hereafter called HM) project” on April 1, 1996, with a mission to reorganize and revitalize the indirect departments and to build a system for ongoing work restructuring. The project name was derived from the “Harmonic Total Management Control System.”

The basic objectives of the HM project were as follows:

- (1) **To identify changes in the market and promote far-seeing management activities**
  - (2) **To promote standardization of operations and centralization of information without being bound by the status quo**
  - (3) **To build an effective company-wide operational framework for continuous market competitiveness**
  - (4) **To increase the trust of customers and distributors**
  - (5) **To build a structure for minimizing operating losses**
- The HM project started with reviewing the role of the organization and how to streamline it by pursuing the best forms of operations via the EDP (electronic data processing) system, which was the backbone of all activities including sales, production, finance, and accounting.

To achieve the goal, they set a subtopic of “Building a new computer system.”

A working group comprising the person in charge of each department was established to conduct actual operations under the guidance of outside experts. Their goal was to “build a total system that covers all operations from receiving orders to collection.” This appears to be just system improvements. However, it was their “challenge to innovate,” and their mantra was “Innovate rather than improve.”

They performed the basic design and detailed design of the new computer system from April to the end of September, and outsourced the subsequent processes.

#### Start of System Development and Its Operation

The development period for the system was from October 1996 to March 1997. As the goals to be achieved by the end of fiscal 1998 after the HM project was well established, they set the following:

- (1) **To reduce the technical review period by half (three days on average)**
- (2) **To achieve an order lead time of two weeks**
- (3) **To reduce inventory levels (0.9 months; 0.7 months at the end of fiscal 1999)**
- (4) **To reduce materials for communicating informa-**

tion

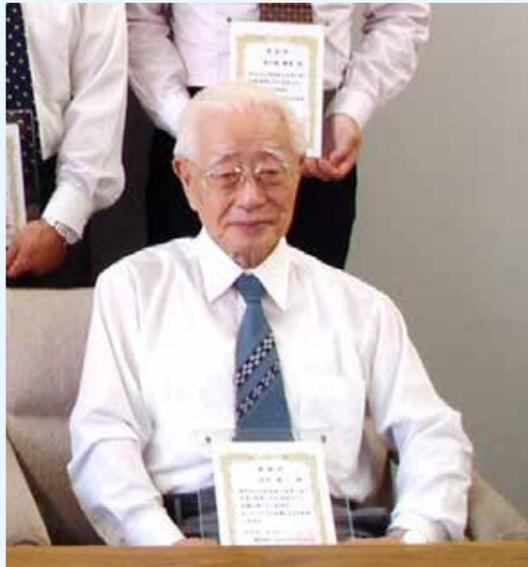
#### (5) To improve the work efficiency of indirect operations

They defined “Five Innovations” to achieve these goals, which encouraged the five groups, namely sales, design/production engineering, production system, information, and operation, to seek specific measures for their innovations.

The core portion of the new computer system based on the HM project underwent test operations and became fully operational in October 1998, six months behind schedule.

However, they decided to suspend it in December due to a flaw in the system. Later, the HM II project was formed to build the system again.

## Achievements of the Engineer Shoichi Ishikawa



Shoichi Ishikawa

### Ishikawa's Encounter with Gears

Shoichi Ishikawa was one of the people who served as the impetus for the founding of HDSI. He was born in Sendai in 1924. He enrolled in an aeronautics course of Tohoku Imperial University (currently Tohoku University) Department of Engineering. To compensate for the serious labor shortage in the midst of the Second World War, he was assigned to the Nakajima Aircraft Company, one of the largest aircraft manufacturers in Asia at the time, under the student mobilization order, and worked on the maintenance of warplanes such as "Zero" and "Ginga."

### Training on Gears under the Guidance of Kin'ichi Shinjo

After the war, he went back to school and graduated, and worked as a teacher at junior high and high schools for about eight years. After working for Tokyo Gas Electric Engineering and then Fuji Automobile, he joined Omiya Machinery, a branch factory of Fuji Automobile, and had an encounter with gears. He learned the basics of gears from Kin'ichi Shinjo, a technical leader of the company. Kin'ichi Shinjo specialized in bevel gears used for propeller shafts of automobiles, and had been granted some patents. Shoichi Ishikawa said that helping him was interesting. At the time, there was no other choice but to use the bevel gear generator developed by the U.S. company Gleason Corporation for gear cutting of bevel gears. Kin'ichi Shinjo was trying to manufacture it in Japan.

After enriching his understanding of gears through these

valuable experiences, Shoichi Ishikawa joined the iron factory of Hasegawa Gear Works in 1955. Shoichi Ishikawa joined the company through his connection with Hiroshi Kameda, his university classmate who had joined Hasegawa Gear Works before him. After joining Hasegawa Gear Works, he worked on the research, development, and commercialization of globoidal worm gears and WN gears.

### Discovery of HarmonicDrive® and His Contribution to Its Commercialization

Shoichi Ishikawa encountered HarmonicDrive® in 1964. He read a translated article of *Machine Design*, the first American mechanical engineering magazine that introduced HarmonicDrive® to Japan. This means he was the driving force behind the discovery.

In later years, he said, "HarmonicDrive® takes advantage of elasticity whereas the conventional gear tries to suppress it. I thought it was a novel and interesting machine element," and "The transition from rigid gears to elastic gears gave us an opportunity to create a new tooth profile theory."

After the technology introduction, he visited the U.S. as part of the "HarmonicDrive® Technical Training Team," and learned all aspects of the technology of HarmonicDrive® at USM.

After the founding of HDSI, he was transferred to HDSI and took part in management as a director. At the same time, he did his research mainly on the tooth profile of HarmonicDrive® while acting as manager of the Development Department and manager of the Engineering Department. However, he once left the company in 1977. After working for another company, he joined HDSI again in 1985 and resumed his research.



Arita, Ishikawa, Hasegawa, and Kameda (from left to right), departing for USM for technical training (January, 1965)



Company trip to Okinawa, November 2005

### Development of the IH Tooth Profile

Among the numerous achievements of Shoichi Ishikawa, the development of the "IH tooth profile" deserves special note. As discussed in detail in the technology section, one of the issues talked about in the company was how to improve the technology level of HarmonicDrive® looking to the 21st century amongst many technical issues occurring in the robot market. As a result of working on the development of tooth profile, Shoichi Ishikawa successfully developed the IH tooth profile in a short period of time. He created a new tooth profile theory that replaced the conventional partial contact with continuous contact, which achieved superior characteristics, including strength of about two times and stiffness of about one and a half to two times that of the conventional HarmonicDrive®. HDSI filed a patent for this innovative invention in 1986.

Initially the "IH" in the "IH tooth profile" was an acronym for "improved harmonic profile" coined by Shoichi Ishikawa. However, Atsuo Tokoro, president at the time, said it was an "acronym for Ishikawa Harmonic" because Shoichi Ishikawa invented it.

In 1996, he participated in the 7th International Power Transmission and Gearing Conference held in San Diego from October 6 to 9 and gave a presentation on the IH tooth profile. He said, "As I participated in this conference and gave a presentation, I realized the importance of expanding my perspective."

### Numerous Awards

The numerous awards he received give evidence of the achievements of Shoichi Ishikawa. In the fall of 1990, he was awarded the Medal with Blue Ribbon. It was awarded for his years of

research on gears and his involvement in the industrial standardization project for gears as an expert committee member on gear standards in the gear industry in Japan.

In 2016, he was awarded the Award for Meritorious Achievement of the JSDE Award for Commemorating of 50th Anniversary for his outstanding achievements in engineering and industrial design by developing practical applications of the HarmonicDrive® speed reducer and improving its performance. In 2018, he was awarded the Academic Experts Award of Merit Celebrating the 80th Anniversary of the Japan Gear Manufacturers Association for his years of contribution to research on gears.



Awarded the Academic Experts Award of Merit Celebrating the 80th Anniversary of the Japan Gear Manufacturers Association, 2018



After the award ceremony with President Nagai

## Achievements of the Engineer Hiroshi Kameda



Hiroshi Kameda

### Starting a Career as an Engineer with the Maintenance of Zero Fighter Planes

Another driving force behind the founding of HDSI was Hiroshi Kameda. He was born in Awa-gun, Chiba Prefecture in 1923. He enrolled in an aeronautics course of Tohoku Imperial University in 1943. He was assigned to the Nakajima Aircraft Company under the student mobilization order, and worked on the maintenance of the "Zero" fighter planes. After being accepted as a candidate engineering officer of the Imperial Japanese Navy, he was reportedly involved in the plan to

build production lines for jet fighters and training planes.

After going back to school and graduating, he joined Okamoto Machine Tool Works, Ltd. and worked on gear cutting of gears as a mechanic for two years. After that, he joined Hasegawa Gear Works. Initially, he worked on gear cutting of gears.

### His Contributions to HarmonicDrive® and Planetary Speed Reducers

Before too long, he became involved in the technology introduction of HarmonicDrive®. In the years when the company was looking for a new technology to introduce, he went to the U.S. with Kiichiro Hasegawa and visited the candidate companies for technology introduction. At that point in time, they had already made up their minds to introduce Harmonic Drive® found by Shoichi Ishikawa. It is not too much to say that the insight of Hiroshi Kameda into technology led to the introduction of HarmonicDrive®. In a recent interview, talking about how he felt when he first picked up HarmonicDrive®, he said, "It was one of my fields of expertise. I thought it was an excellent idea and I felt outdone, but I became more interested." After the introduction was decided on, he prepared business plans to be submitted to USM by day and night.

In 1965, he went to the U.S. with Shoichi Ishikawa and Mitsuo Arita as part of the "HarmonicDrive Technical Training Team" and learned all aspects of the technology. He later worked on the improvement of HarmonicDrive® and the development of application products.



HarmonicDrive® Technical Training Team



Hiroshi Kameda (when he was an assistant professor of the University of Tsukuba)



Hiroshi Kameda and Shoichi Ishikawa

After that, Hiroshi Kameda was transferred from Hasegawa Gear Works to HDSI. After joining Hasegawa Gear Works again, he became an assistant professor of structural engineering at the University of Tsukuba in 1978, and became a professor in 1986. Around that time, he made a proposal to HDSI to work on planetary speed reducers. In 1987, he joined HDSI again, and worked on the research and development of the technology related to planetary gears, as well as commercialization and improvement.

### Involvement in the Development of Robotic Hands

In 2000, he became deeply involved when HDSI received a request from Ishikawa Group Laboratory of the University of Tokyo regarding robotic hands. The laboratory conducted research on vision sensors. As part of the research, they focused on the sensory-motor integration of the human brain, and worked on the construction of an engineering brain-type information processing system that could allow for flexible recognition and behavior. Especially focusing on the hand, which played an important role in the human motor function, they were trying to construct an ultra-fast, high-performance robotic hand system that far exceeded the performance of humans and conventional robots. As a result of undertaking the task of designing and manufacturing the finger mechanism, he worked on the research and development of HarmonicDrive® suitable for the knuckle joint mechanism. As a result, in 2001, he completed the finger module comprising the world's small-

est HarmonicDrive® with an outside diameter of 13mm, ultra-small AC servo motors, and bevel gears. At the time, using multiple bevel gears in combination was regarded as preposterous. However, Hiroshi Kameda was absolutely confident that it would work based on his own experience of cutting bevel gears for about three years after his graduation from university. It was in fact successful, and the robotic hand could catch a falling ping-pong ball. Hiroshi Kameda remained active on the front lines until recently.

He passed away in 2020 at the age of 98.



Robotic hand of Ishikawa Group Laboratory of the University of Tokyo

## Expanded Applications of HarmonicDrive®

The 1990s was a time of expanded applications of HarmonicDrive®. Listed below are two of its unique use cases: the application in the large-scale optical/infrared telescope “Subaru” on the peak of Mount Mauna Kea on the island of Hawaii, and the application in the Mars Exploration Rovers of NASA.

### Application in the Large-Scale Optical/Infrared Telescope “Subaru”

The National Astronomical Observatory of Japan decided to build a large-scale telescope with the world’s highest sensitivity at an altitude of about 4,200m on the peak of Mount Mauna Kea on the island of Hawaii to collect and provide highly accurate information about space. The name of the telescope was “Subaru.”

The primary mirror (antenna for collecting light) at the core was cup shaped. Its effective diameter was 8.2 m, which was the largest in the world. At the time of its design, the maximum diameter of the primary mirror was believed to be about 4 m in terms of fabricating technology and precision. For Subaru, a diameter of about two times the maximum was set out.

A large primary mirror might not be able to focus light or radio waves due to deformation or unevenness of a surface constantly affected by heat, wind, and orientation (gravity). To eliminate the causes of the defects to keep the mirror surface in optimal condition, a hard, thick mirror had to be made. However, a primary mirror with an effective diameter of 8.2 m built with the technology of the time would be extremely

heavy, requiring a large, robust structure to support it. The problem was that the cost of building it would be astronomical. This gave rise to the need to create a “magic mirror,” a thin, lightweight mirror free of the effects of heat and wind. It was HarmonicDrive® that helped realize it.

The “magic mirror” was built by creating 44 hexagonal segments with a side length of 1.5 m, which formed a cup-shaped mirror of 8.23 m in effective diameter and 0.2 m in thickness when combined, and coating it with aluminum. One of the challenges to overcome was to reshape the primary mirror deformed due to changes in wind or temperature or its orientation into the optimal shape. For the “active support mechanism,” 264 linear actuators with HarmonicDrive® were used.

The linear actuator consisted of a motor with a double reduction gear head with CSS-14 and CP-16 and a ball screw attached to its end. They were installed with their ends attached to the back of the primary mirror. The surface of the primary mirror could be kept in the ideal shape by pushing or pulling the surface with the linear actuators.

The linear actuators of HDSI achieved a superior positional precision that could limit the deviation from the ideal shape within 0.1 μm (1/10000 mm). This is equivalent to leveling the ground to an error (difference in height) of 1mm or less in a circular land with a diameter equal to the distance between Tokyo and Nagoya.

Subaru required the top unit (very much like a microphone) for collecting various types of information from space to be replaced depending on the type of information. HarmonicDrive® components were used in the robot to make the replacement. Harmonic Drive® products were also used in the system for the annual maintenance of the primary mirror, i.e., dissolving and washing off the old aluminum coating on the surface of the primary mirror and vacuum depositing a new coating.

Test observations with Subaru were started in 1998, and production observations were started in 2004.



Large-scale optical/infrared telescope “Subaru” (by courtesy of the National Astronomical Observatory of Japan)

### Applications in Space Technology

HarmonicDrive® products have also been used in space. One example is the Mars rover “Sojourner” that successfully landed on Mars on July 4, 1997 (July 5 Japan Time). HarmonicDrive® FR-40 was used in the system driving the solar paddle of the probe launched by NASA and successfully fulfilled its role. The solar paddles of the probe were folded around the probe and extended after landing. HarmonicDrive® was used in the mechanism.

Later, it was again used in the Mars Exploration Rovers launched by NASA in 2003 and landed on the surface of the Mars on January 4 and 25, 2004.

The main mission of the two rovers, named “Spirit” and “Opportunity,” was searching for evidence of life on Mars (e.g., bedrock and signs of salt water). They were the size of a golf cart and had six wheels. They also had a robotic arm for collecting rocks, high-performance cameras, and chemical analysis systems. The rovers named “Spirit” and “Opportunity” performed their missions for six years and 14 years, respectively.

A total of 19 units of HarmonicDrive® were used in the Mars rovers for driving wheels, steering, robot arm joints, cameras (positioning of the camera, raising of the mast, and adjustment of the camera direction), and high-sensitivity antennas.

Furthermore, HarmonicDrive® units have been used in a wide variety of applications, including the driving of the wheels of lunar rovers, the system for controlling the attitude of the solar paddles (with solar panels that supply power to the satellite) to an appropriate position with respect to the Sun, and the system for aiming the antenna, critical for communications in space and on the ground, at the ground base.

### Advantages of Using HarmonicDrive®

HarmonicDrive® was optimal for these applications because it was the most lightweight and compact speed reducer with the highest positioning accuracy. Its lightweight feature was especially emphasized. This is because one of the challenges of designing a rocket is reducing its weight. A rocket needs large amounts of fuel, and its weight accounts for about 70% of the total weight. The cost of fuel to bring a part of 1g to the intended location in space by using the rocket is estimated to be several millions of yen. Therefore, lightweight parts with high performance are essential.



Mars rover (Rover image created by Dan Maas, copyright and provided courtesy of NASA/JPL-Caltech)

Space exploration has a number of important objectives, such as resource development on the Moon and planets and use of outer space. This includes discovery and development of valuable resources that cannot be harvested on the Earth, use of high vacuum, space power generation, and transmission. In addition, satellites are used to observe space in combination with land-based radio telescopes as well as to observe the global environment (e.g. observations of desertification, deforestation, ozone holes, and air pollutants). The applications of HarmonicDrive® in these projects are our achievements to be proud of.

# Chapter 5: Development

## Listing on the Over-the-Counter Market and Focused Efforts on Overseas Expansion

### 1998-2006

#### 5-1 Listing on the Over-the-Counter Market

##### Listing on the Over-the-Counter Market

The priority goals of HDSI to “revitalize and enhance the company-wide quality assurance activities” in the medium-term business plan until 1997 included public listing along with the stabilization and review of ISO 9001.

HDSI was faced with repeated setbacks during the preparation for public listing. In particular, it took time to deal with the ownership ratios of the parent companies and cross-shareholding with foreign companies. As a result, HDSI missed two great opportunities to get listed, such as when the market was active.

HDSI also struggled with completing an enormous amount of paperwork. Despite the assistance of the managing underwriter, the people in charge of the preparation carried on working every day, struggling with the meticulous requirements.

On March 20, 1998, eight years after HDSI started the activities toward public listing, the Japan Securities Dealers Association finally approved the over-the-counter

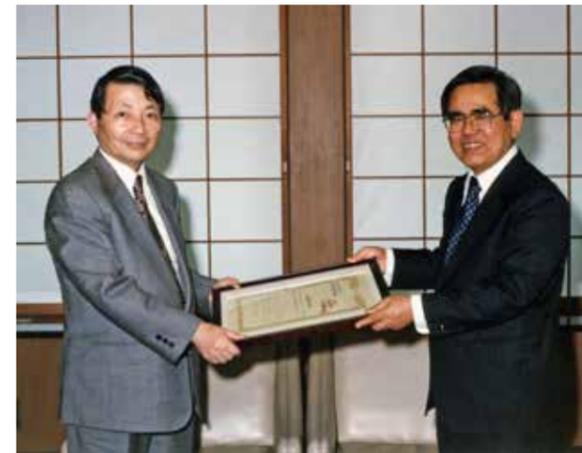
(OTC) listing. This was the moment when HDSI took the first step in the transition from a private company to a public company.

In OTC listing, the Japan Securities Dealers Association approves the stock price released by the company and publication of the documents of the issuing company. JASDAQ was the OTC market.

Held accountable for its growth and significance by shareholders and institutional investors, HDSI was determined to make company-wide efforts to strive for further development and expansion on the occasion of the OTC listing.

In response to the determination of the OTC listing, HDSI placed advertisements for the listing and public greetings in the Nihon Keizai Shimbun and securities industry papers.

A disturbance occurred immediately after the public listing. At the time, the IT bubble that overinflated in the 1990s was about to burst. Affected by the situation, HDSI could not achieve the results forecast at the time of the listing. The stock price dropped as might be expected, and HDSI received complaints from the shareholders.



Approval of the OTC listing



From left to right: General Manager of Management Division Usui, Vice President Arakawa, President Ito, and Executive Director Kawakita

##### First General Shareholders' Meeting

On June 24, 1998, HDSI held the first general shareholders' meeting after the public listing at the Capensia Hall of Art Hotels Omori. The meeting was scheduled away from busy days so that as many shareholders as possible could attend. After the general shareholders' meeting, HDSI held a social gathering with shareholders and

officers, where President Mitsumasa Ito talked about the management philosophy and products of HDSI, industry trends, and future prospects. The year-end dividend per share at the time was 15,000 yen (annual dividend of 20,000 yen).



Newspaper ad about the OTC listing



Telephone cards distributed to celebrate the OTC listing





First general shareholders' meeting held in June 1998



Notification about the new website



ISO 14001 project team

### Opening of the Website

The OTC listing required HDSI to publicly disclose its financial information. As more competitors opened their websites, HDSI decided to publish information on a website. HDSI expected to create a chain effect where using a combination of digital media, such as a website, and conventional analog media, such as newspaper and magazine ads and catalogs, would generate sales. HDSI also expected that such a website would allow it to provide information to a broad base of customers, receive catalog requests and inquiries by email, and publish instantaneous information.

HDSI opened its website in October 1998. The website had pages such as Corporate Information, Recruit Information, Product Information, Principles of HarmonicDrive®, and Financial Information, as well as the “Hot News” area for providing the latest information about new products and events of HDSI.

### Issuance of Convertible Bonds

In August 2004, HDSI resolved to issue convertible bonds for a total of 3 billion yen to raise external funding. On September 21, HDSI issued “Euro-Yen-Denominated

Convertible Bonds with Stock Acquisition Rights Due 2009.” The period for making a request to exercise stock acquisition rights was set to be from October 5, 2004 to September 7, 2009. The time of maturity was set to be September 21, 2009.

The last day of the exercise (when the rights were to be exercised in full amount) was set to be February 5, 2007, but all the rights were converted to shares more than two and a half years before the time of maturity due to the rising stock price of HDSI at the time.

## 5-2 | Acquisition of ISO 14001 Certification

### Background of the Acquisition

The 1990s was a period of global environmental problems that provoked active discussions worldwide. It is not too much to say that the prime cause of the global environmental problems was the production activities of developed countries based on the premise of mass production, mass consumption, and mass disposal. As it was believed that corporate activities accounted for 70 to 80% of environmental impacts (environmental degradation due to civic activities or business activities in general), it

was essential to make a fundamental change in excessive production activities to resolve the problems.

As the first step toward the change, a new international standard was born based on the idea of making corporate activities more environmentally friendly. The international standard was the ISO 14001 Environmental Management System released in September 1996.

The standard specified a framework that an organization could follow to protect the environment and deal with changing environmental conditions while keeping balance with social and economic needs. The benefits for a company acquiring the certification included reduction of environmental costs, avoidance of environmental risks, improvements and changes in business relationships (i.e., a company with the ISO 14000 series certification had an increased chance of being selected as a supplier of raw materials or parts), and improvement of the company's image and credibility.

In October 1996, HDSI decided to acquire the certification. In fiscal 1997, HDSI set the major goal of acquiring ISO 14001 certification, and started the ISO 14001 project team in November. Inside the company, HDSI promoted a better understanding of ISO 14001 through

the in-house magazine HD.Times and explanatory meetings for different groups.

As ISO 14001 not only promotes environmental improvement but covers methods of manufacturing environmentally friendly products, it addresses how development and design should be conducted. As in the case of the quality ISO standard, to acquire ISO 14001 certification, a company needs to construct an environmental management system including documentation and recording and make continual improvements after the acquisition. The company also needs to address the requirements of ISO 14001, namely General Requirements, Environmental Policy, Planning, Implementation and Operation, Checking and Corrective Action, and Management Review (review by the management). Among these requirements, the core of an environmental management system is the environmental policy. HDSI established the Basic Environmental Philosophy and Basic Environmental Policy at the management meeting on April 25, 1997.

### Preliminary Review and Environmental Review

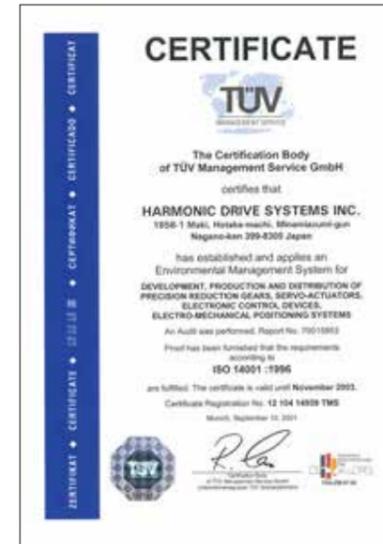
On September 9 and 10, 1997, TÜV conducted the preliminary review of the environmental management



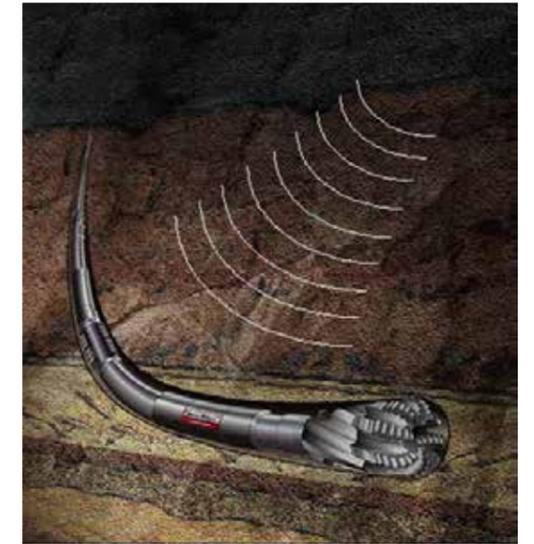
First audit for ISO 14001



Final review for ISO 14001



ISO 14001 certificate



Bent sub (by courtesy of Halliburton Sperry Drilling Services)

**Basic Environmental Philosophy**

Located at the foot of the Alps with an abundance of water and greenery, Harmonic Drive Systems Inc. will contribute to the preservation of a healthy global environment and the realization of an affluent and comfortable society by providing society with superior technologies and services in harmony with the rich natural environment through all of our business activities based on our deep understanding of corporate social responsibility to achieve harmony with the global environment.

**Basic Environmental Policy**

- 1. We will strive to assess the environmental impacts throughout the entire production process from development to disposal and collection and develop environmentally friendly technologies.
- 1. We will observe the environmental laws, set voluntary control standards, and continuously improve our environmental management levels through annual reviews.
- 1. We will strive to reduce environmental impacts by ensuring efficient use of resources and energy and reducing and recycling waste and emissions in our business activities.
- 1. We will set objectives and goals, voluntarily control action plans, and make continual improvements to implement the policy.
- 1. We will provide education and training to raise the environmental awareness of employees and engage in awareness-building activities.
- 1. We will participate in local environmental preservation activities and strive for harmonious coexistence with local communities.

system as in the case of ISO 9001 certification. They inspected both inside and outside of the factory premises, reviewed documents, and exchanged opinions with the project members.

At the time of the preliminary review, HDSI internally published the environmental objectives to be achieved in 18 months from October 1997 to March 1999. The specific efforts included proper waste treatment, measurement of the work environment (checking air pollution at the exhaust openings of the work floors of the departments using organic solvent), prevention of oil leakage on the manufacturing floor, and 5S. As a company, HDSI also tried to save natural resources in various areas that directly affected costs. For example, HDSI worked on organizing, integrating, and standardizing a wide variety of oils and coatings it had been using as a result of adopting them as recommended by manufacturers or requested by customers. HDSI also reduced the amounts of copier paper, cardboard, waste, and Styrofoam.

**Environmental Audit, Final Review, and Acquisition of Certification**

After that, after the first environmental audit in Janu-

ary 1998, TÜV conducted the final review in a period of three days from March 10 to 12. HDSI acquired the ISO 14001 certification on April 9.

After that, HDSI formed four working groups based on a thorough understanding of the basic manual to promote activities to reduce environmental impacts in day-to-day operations. The four working groups were: 1. Organic solvent control; 2. Equipment and work environment control; 3. Waste control; and 4. Energy saving control. Each of the working groups created an environmental management program, determined a target value, and promoted its activities to achieve it. Later, in addition to the four working groups, the General Affairs Department was formed a working group for environment conservation during the development of new products (management of greenery areas on the factory premises). The target values were reviewed annually to improve the environmental management.

5-3 | **Development of the Bent Sub (for Oil Drilling)**

**Beginning of the Development**

At the time, most of HDSI's products were intended for

the precision positioning market. Some of the products grew into a large business as a result of meeting demand from customers. A typical example is the bent sub used for oil drilling.

As the main player in oil drilling changed from onshore oil drilling to offshore oil drilling, the drilling method of drilling into the ocean floor with drilling assemblies from platforms became mainstream. In most cases, oil reserves in the ground extended horizontally. For efficient drilling for oil, the oil well initially drilled vertically had to be turned in the horizontal direction.

One of the methods at the time for turning the oil well in the horizontal direction was to use a wedge called a whipstock and let the drilling assembly deflect naturally along the strata. However, this method had to be used many times until the drilling assembly became horizontal, which required enormous time.

Against this background, the Japan National Oil Corporation (disbanded in 2004) initiated a project to conduct research and development of an oil drilling rig using new technology, and commissioned its facilitation to Sumitomo Metal Industries, Ltd. (currently Nippon Steel Corporation). In the winter of 1990, a representative



At the time of the establishment of HPI



Shop floor of HPI

from Sumitomo Metal Industries visited the Toyoshina Factory on referral from one of HDSI's distributors. The rig was in a sense a drilling robot, so the person visited HDSI, which was famous for speed reducers for robots.

The person sought advice on the development of a mechanism that could freely bend the tip of the rig. An engineer of HDSI suggested that such a mechanism could be built by using a combination of a hollow-shaft HarmonicDrive® and eccentric disc. The suggestion was accepted immediately.

#### Completion of the Bent Sub

The project officially started in 1992. After that, the project worked on the development for eight years, manufacturing one prototype per year. This mechanism was named the “bent sub.”

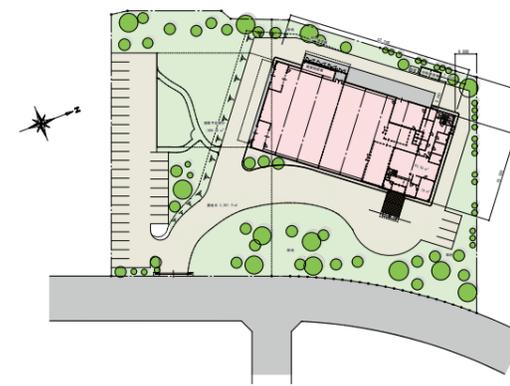
In 2000, in the final stage of the project, they conducted a demonstration experiment at Kashiwazaki, Niigata, to confirm that it could bend the oil well. They brought out the technology and aimed to put it to practical use.

However, there was no company in Japan that needed the bent sub. As such, the Japan National Oil Corporation aimed to promote its widespread use overseas. There

was a long period when no company took any notice due to the widespread use of conventional technologies such as changing the orientation of the rig by hydraulic power. Only one company showed interest. It was Sperry-Sun Drilling Services, Inc. (hereafter called SSDS) in the United States. The Japan National Oil Corporation held a series of negotiations with SSDS, and transferred at no cost the bent sub technology with the patents, provided that they afforded help for oil drilling in Japan.

The project of the Japan National Oil Corporation developed many devices, but it was only the mechanism developed by HDSI that was adopted by SSDS. Accordingly, HDSI became responsible for its production and delivery. The project lasted for a total of 12 years, eight years for development, two years for looking for a partner for putting it to practical use, and two years for putting it to practical use at SSDS. Today, HDSI delivers the product to Halliburton, one of the major drilling services, which took over SSDS in 2000.

The business grew significantly to generate about 1 billion yen in annual sales for a time, but the market is shrinking. One of the reasons is that the device never breaks and requires no renewal. In recent years, onshore



Schematic drawings of the new HPI building (November 2000)



North side elevation. Scale 1:200



East side elevation. Scale 1:200

shale gas drilling is becoming mainstream, and no significant growth in sales can be expected in the oil drilling industry.

The technical aspect of the bent sub will be discussed in the technology section.

#### 5-4 Establishment of the Subsidiaries

##### Establishment of HD Logistics, Inc. (HDL)

The turn of the 21st century was a period when HDSI solidified its group management structure by establishing subsidiaries. The first of such subsidiaries was HD Logistics, Inc. (hereafter called HDL) established as a logistics subsidiary on April 20, 1999. With capital of 10 million yen, it was wholly owned by HDSI.

The purpose of establishing HDL was to reduce logistics costs by delegating logistics and its management, stock receiving, warehouse management, product packaging, and transportation. HDL started to operate as a logistics company with its own expertise while utilizing the management resources of the parent company HDSI, including product knowledge and sales information. HDL strove to manage and conduct transportation, pack-

aging, and information provision under a rational system and integrate logistics by partnering with truckers and warehousemen.

##### Establishment of Harmonic Precision Inc. (HPI)

The next subsidiary following HDL was Harmonic Precision Inc. (hereafter called HPI) established on July 1, 1999. The business domain of the company was the production of cross roller bearings (hereafter called CRB). As the product mix of HarmonicDrive® changed from single components to unit products, the CRB played an important role as one of the main components of the unit products.

Until then, Akahane KOKI Inc. performed the production of CRB, including polishing and assembly, with workers dispatched from HDSI.

The business relationship with Akahane KOKI started when Chairman Yoshiro Nakajima, who was president at the time, looked at the signboard of HDSI near Hotaka Shrine and got interested, and made a sales pitch. However, HDSI concluded that the company lacked the machining techniques to meet the precision requirements of HDSI. After about five years, HDSI placed its first



Groundbreaking ceremony for the construction of the new HPI building (November 2000)



Cafeteria of HPI



New HPI building (March 2001)

order with Akahane KOKI because of their improved machining techniques.

In an interview conducted for compiling the company's history, Chairman Yoshiro Nakajima said in retrospect: "The precision requirements were difficult to meet. A dimensional precision of 0.09 mm was required for machining of castings. We were barely able to meet their expectations as a result of trial and error in terms of the cutting speed, rotation speed, and method to secure the workpiece on the machine."

The order quantity was initially about 50 units per year, and increased gradually.

However, for sustainable development, HDSI had to bring the production of this high-value-added product to its ownership at any cost. To achieve this, HDSI decided to build an integrated production system for CRB by introducing new heat treatment technology in addition to the polishing and assembly technology accumulated at Akahane KOKI for independent business development as a manufacturer.

HDSI and Akahane KOKI established HPI as a 65/35 joint venture. The new company was located at a factory in Shiojiri rented from Akahane KOKI. HPI started to

operate with a small group of 13 employees.

As described earlier, the business domain of the company was the production and sales of CRB. The company decided to promote efforts with a view to application products to develop into a precision equipment manufacturer in the future.

Later, HPI decided to build a new office building. They chose the Matsumoto Rinku Industrial Complex as the building site. In the site area of 7,172 m<sup>2</sup>, HPI planned to construct a partially two-story SRC building with a total area of 1,530 m<sup>2</sup> for future extensions. After the ground-breaking ceremony on November 9, 2000, the construction was started on November 15, which proceeded smoothly. The factory portion was provisionally delivered on February 25, 2001. From March 2 to 4, HPI moved from the old factory in Shiojiri to the new factory, and started to operate on March 5.

The new factory was appropriate as a precision machining factory. In addition to the emphasis on the foundation and air conditioning system, the factory employed a special waste water treatment method to be a factory that could achieve compliance with ISO 14000, which the company was planning to acquire. No telephone was



Relocation of HAD to the Toyoshina Factory (2004)



Party celebrating the establishment of HAD



Machining shop floor of the HAD factory (2004)

placed on the office desks, and everyone had an internal PHS phone instead.

The factory had extensive welfare facilities, such as showers in the locker room, bidet toilets, and a well-lit cafeteria with a great view. As the factory was located in an industrial complex, small mounds with trees and lawn were placed near the factory to create an image that the factory was in a greenery area.

#### Establishment of Harmonic AD, Inc. (HAD)

The third subsidiary was Harmonic AD, Inc. (hereafter called HAD) established on April 1, 2003. At the time, HDSI had two families of speed reducer products, namely HarmonicDrive® and the high-precision planetary gear AccuDrive®, which had different characteristics, market circumstances, and product appeals. The market share of HDSI in the market of speed reducers for precision control at low reduction ratios was a little less than 30% in domestic sales and negligible in sales overseas. The situation was far from dependable. HDSI had been developing the AccuDrive business to make a leap forward, but the business conditions were severe. There was fierce competition in the planetary gear speed reducer markets both in

Japan and overseas, in terms of delivery time and price, let alone performance. Against this background, HDSI started to launch an initiative to make the business independent since fiscal 2000.

The primary focus of the initiative was implementing the system with a select few to change the cost structure as well as to improve profitability. Another goal was to contribute to greater profitability of the HDSI Group by increasing market competitiveness.

The theme of the initiative was "increasing the sales of AccuDrive® products by building a robust structure, diving into a competitive environment, taking full responsibility for management, and remaining viable." The initiative also included ongoing development of the business through the development of products that matched the needs of customers, further improvement of productivity, shorter delivery time, and cost competitiveness.

To achieve independence, HDSI was to establish a new wholly owned company, and transfer the business of the AccuDrive Division to the company. After the company split plan was approved at the board meeting on January 24, 2003, HAD was born on April 1 of that year. The immediate targets were 50,000 units per year and 2 bil-



Harmonic Concert celebrating the 30th anniversary



Harmonic Lecture celebrating the anniversary by Teru Miyamoto



Trip to Hokkaido celebrating the 30th anniversary

lion yen in sales. The company started to operate in the Hotaka Factory of HDSI.

Subsequently, HDSI provided support for HAD in terms of sales and material procurement to improve the total strength of the entire HDSI Group.

Soon after starting its operation, HAD decided to relocate to the old Toyoshina Factory because its workload exceeded the initiative for independence. The factory had been rented to Sony Corporation and used as a service location after HDSI transferred all its functions to the Hotaka Factory. As a result, restoring the environment where machine tools could be used took a variety of reconstruction work, but only one month was available for the reconstruction. Nonetheless, the company completed the relocation from September 4 to 5, 2004, as scheduled, and was ready for production and shipment on September 8.

### 5-5 | Celebration of the 30th Anniversary

#### Harmonic Concert and Harmonic Lecture Celebrating the 30th Anniversary

In 2000, HDSI celebrated the 30th anniversary and

undertook a number of projects celebrating the anniversary. On May 20, 2000, HDSI held the 18th Harmonic Concert titled “Harmonic Concert Celebrating the 30th Anniversary” at the Toyoshina Community Center. Mitsuko Shirai (mezzo-soprano), Christoph Prégardien (tenor), and Hartmut Höll (piano) played *Italienisches Liederbuch, nach Paul Heyse* composed by Hugo Wolf. The concert was a great success with 629 people in the audience, including some standees.

The concert tried something new for the first time. The Japanese translation of each of the 46 lieder was displayed in the venue to help the audience understand the story. This was also new to the performers, but they were successful after a process of trial and error.

At the gathering held after the concert, President Mitsumasa Ito said:

“The first song *Even Small Things* says, ‘Even small things can delight us, Even small things can be precious.’ Similarly, I would like Harmonic Drive Systems to be a company that delights people and be precious even though it is small.”

He emphasized that the company would continue to grow into the future.

On October 6, HDSI held the Harmonic Lecture celebrating the anniversary by Teru Miyamoto at the Hotaka Community Center. The title of his lecture was “A 6,700 km Journey Along the Silk Road.” He also talked about how he wrote two of his major works, *Doro no Kawa* and *Hotarugawa*.

#### Celebratory Party and Trip to Hokkaido

On August 29 of 2000, HDSI held a celebratory party celebrating the 30th anniversary at the Kujaku Banquet Hall of Hotel Buena Vista Matsumoto in Nagano.

HDSI also hosted a trip celebrating the anniversary from September 14 to 16. A total of 181 people, including the employees of HDSI and the subsidiaries as well as temporary workers, took a trip to Hokkaido.

They left the factory on buses in the early morning of the first day, and joined the people from the Head Office and offices at Haneda Airport. They took a flight to Chitose, Hokkaido. In Hokkaido, they enjoyed the view of the ranch and a BBQ at the Northern Horse Park, and moved to Takimotokan in Noboribetsu where they stayed. They had a blast playing a bingo game at the banquet. On the second day, they enjoyed free activities, such as going

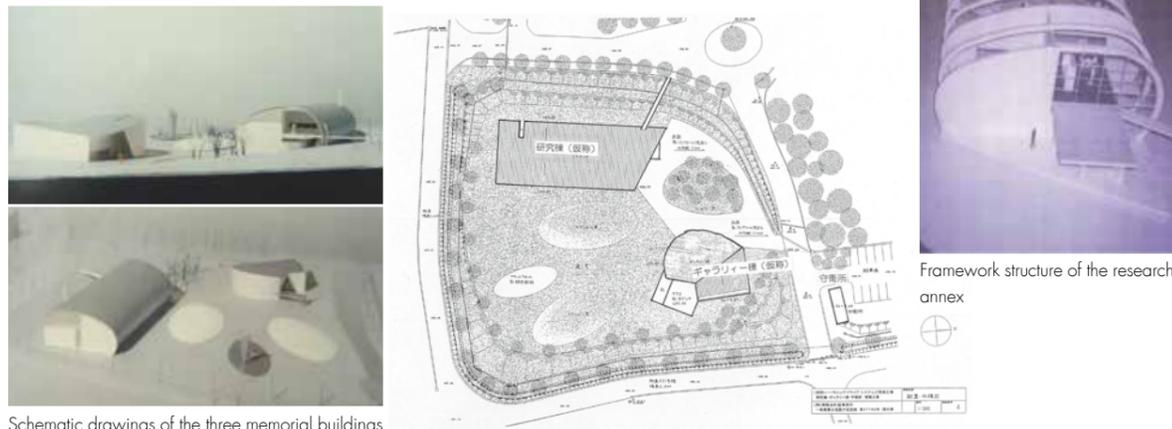
sightseeing in Otaru, playing golf, and going fishing. After that, they stayed at a hotel in Sapporo. On the last day, they went shopping in Sapporo and took a tour of a beer factory. After lunch, they took a return flight from New Chitose Airport to Haneda. The factory group went back to Azumino from Haneda Airport by bus. On both the outward and return flights, the group was so large that they split up and flew on seven planes.

### 5-6 | Construction of the Memorial Buildings Celebrating the 30th Anniversary

#### Decision on the Construction Project for the Three Memorial Buildings

In January 2000, HDSI started to develop a plan to construct memorial buildings for the future technology of HDSI as a project celebrating the 30th anniversary. After a great deal of consideration, HDSI decided to construct three memorial buildings at the Board of Directors’ meeting held in August 2000.

The three buildings were the research annex for the development of fundamental gear technology, the art gallery mainly used as a welfare facility for employees, and the guardhouse for access control and security of the



Schematic drawings of the three memorial buildings celebrating the 30th anniversary

Framework structure of the research annex

premises. HDSI decided to develop beforehand the area to blend with the factory's landscape and the surrounding environment and lay out the buildings in the area, rather than simply building three buildings. HDSI commissioned the design and supervision to Maki and Associates, headed by the world-class architect Fumihiko Maki, and the construction to Noguchi.

When drafting a concept for each of the buildings, Fumihiko Maki came up with two themes, "motion" and "flow." In Motion Control, the basis of HDSI's products, HarmonicDrive® converts steady motion into complex and fine motion by slightly deforming from a perfect circle. In addition, the theme of the paintings of Yoshikuni Iida, planned to be displayed in the art gallery later called "IIDA-KAN," is motion. The theme of "motion" was derived from these ideas. The theme of "flow" was derived from the flowing and dynamic touch of Yoshikuni Iida.

#### Explanatory Meeting for Local Residents

On December 8, 2000, HDSI held an explanatory meeting for local residents about the construction of the memorial buildings at the Maki Community Center. The Machizukuri Ordinance of Hotaka Town mandates busi-

ness operators to hold an explanatory meeting when making a land use change of 500 m<sup>2</sup> or more or conducting a development project of non-residential buildings with a total area of 200 m<sup>2</sup> or more. The intent is to discuss the details of the project and construction methods with local residents.

The attendants of the meeting included the owners of the lands neighboring the Hotaka Factory, the mayor of Maki, Hotaka-machi, and the members of the Development Council from the local community, and the general manager of General Affairs, the director of the Quality Assurance Promotion Office, auditors, and members of the General Affairs Department from HDSI. Maki and Associates and Noguchi also attended as the parties involved.

It was explained that, in addition to the purpose and overview of the construction, the art gallery would contribute to cultural activities in the local community and that the three buildings were laid out and designed to form a park area that would blend with the landscape of the site. There were questions and opinions about the environmental efforts of HDSI outside the premises. HDSI obtained a consensus by promising to submit a written pledge to deal with any problems with sincerity.



Explanatory meeting for local residents



Ground-breaking ceremony for the construction of the memorial buildings celebrating the 30th anniversary

#### Construction of the Research Annex, Art Gallery, and Guardhouse

On April 2, 2001, a ground-breaking ceremony was held in advance of the construction of the memorial buildings. The attendees included President Mitsumasa Ito, officers, and other persons involved in the factory, Maki and Associates, which was responsible for the design and supervision, Noguchi, which was responsible for the construction, and representatives from the local communities.

For the roofs and exterior walls of the three buildings, industrial materials such as metal, concrete, and glass were used as they were to symbolize HDSI's involvement in advanced technology. Industrial materials such as lead and nylon ropes were also used for the sculptures of Yoshikuni Iida to represent his way of expression of giving tribute to this era of "modern age." Industrial materials, deeply related to the works of Yoshikuni Iida, were the opposite of natural materials. Fumihiko Maki said, "I hoped that these building materials would blend with the beautiful nature of Hotaka in a contrasting manner."

A great deal of thought was put into the layout of the three buildings. The research annex, art gallery, and

guardhouse had different sizes and functions. Regarding the layout of the three buildings, Fumihiko Maki said, "Inspired by the environment surrounding the factory, such as the views of the premises of the Hotaka Factory and Azumino toward the east, gentle slopes on the mountains, and green of the trees, I designed the layout by placing emphasis on preserving the broadness and natural greenery."

The research annex and art gallery were placed along the edge of the site, and the guardhouse was placed at the corner of the existing parking area across the road to create a moderate contrasting relationship with the art gallery. The layout plan was determined to define the relations between the unique buildings with different functions and to create harmony with the surrounding environment.

#### Decision on the Name "TRIAD"

The popular name for the research annex "I-KAN," art gallery "IIDA-KAN," guardhouse, and the surrounding area was determined to be "TRIAD." This was suggested by the designer Fumihiko Maki. The name represented the harmony between the three memorial buildings and



A bird's-eye view of the factory



Research annex "I-K KAN"



Art gallery "IIDA-KAN"



Guardhouse

the surrounding space. "TRIAD" means a group of three in English, and a set of three notes in music.

On April 13, 2002, Maki and Associates held a preview of TRIAD, inviting about 80 people including local residents.

#### Overview of the Three Buildings

The highlights of each of the three buildings are as follows.

##### • Research annex "I-K KAN"

The research annex was built to provide a production environment and measurement environment to ensure the implementation of a high level of ideas based on the policy that HDSI would strive for higher precision in the motion control field.

The two themes of the construction were as follows.

- To strive for precision machining and measurement to reduce the angular transmission error of HarmonicDrive® by 1/10 of the current performance by constructing the research annex
- To accumulate internally the expertise for which HDSI had been dependent on other companies and to improve and pass down the skills

The basic requirements for the building specifications

included no change in temperature or humidity, floors rigid enough not to be affected by earth oscillations, and maintenance of positive pressure to ensure an indoor environment for manufacturing high-precision prototypes. To achieve this, a highly airtight building structure with reinforced concrete floors with a thickness of 1 m was selected. Because temperature and humidity control was critical, the air conditioning method, direction, and wind pressure were determined by running numerous simulations on a supercomputer.

The design of the building was unique. One of the eye-catching features was the asymmetric structure with a slightly deformed semi-cylindrical cross-section. The structure with seamless walls and ceilings as in an Antarctic research station could easily achieve airtightness and high thermal insulation as well as contain the spiral flow of air-conditioning air. Furthermore, the structure symbolized the curve of the IH tooth profile developed by Technical Advisor Shoichi Ishikawa.

The building was named "I-K KAN." It was named after the initials of Technical Advisors Shoichi Ishikawa and Hiroshi Kameda, who achieved numerous achievements as pillars of the company's technology since the introduction of HarmonicDrive® technology.

Immediately after it was delivered on April 2, 2002,

I-K KAN started to operate toward the goals of the Precision Production Engineering Development Office.

##### • Art gallery "IIDA-KAN"

The construction of the art gallery was planned because more than 120 oil paintings of Yoshikuni Iida that were painted in the period he was active as a painter were to be on loan to HDSI. HDSI decided to construct an art pavilion to store them for playing a role in the preservation and storage of outstanding works of art as part of the company's cultural activities. HDSI also aimed to improve the sensitivity of employees based on the belief that "everyone aiming to be a first-class person should be exposed to things that are first class to improve their sensitivity."

There is a background story to the latter idea. In the past, HDSI had been accumulating a vast store of knowledge based on ad-hoc creative thinking. However, such knowledge, when turned into ready-made ideas, might inhibit an exponential leap forward. HDSI expected the employees, when facing such an obstacle, to return to flexible thinking and improve their sensitivity by exposing themselves to the works of Yoshikuni Iida.

The art gallery had a simple design like the research annex. Under the guidance and cooperation of Atsuo

Yamada, a curator at the Meguro Museum of Art, Tokyo, HDSI prepared the interior such as the storage walls, floor color, and lighting, determined how to display the works, and created a brochure to create the appearance of an art museum.

The interior layout employed a circuit-style exhibition space so that visitors could appreciate the works successively and return to the initial location without turning back. The sculpture exhibit hall, also serving as the entrance hall and lounge, was surrounded by curved walls that embraced the sculpture along the flow of the circuit-style space. To the contrary, the exhibition space for two-dimensional works such as paintings was surrounded by flat walls.

The art gallery was named "IIDA-KAN" after the sculptor Yoshikuni Iida, who created the works that it stored and displayed.

##### • Guardhouse

The guardhouse was structured to look as if it was slightly off the ground, with an image of a horizontal ruler for the visualization of the gentle slope at the foot of the mountain. The shape also served as a method to protect the monitoring panel for the light electrical equipment used for security of the Hotaka Factory from rainwater flowing



Opening of IIDA-KAN

downhill in heavy rain.

### 5-7 | Opening of IIDA-KAN

#### Opening of the Art Gallery and Its Addition to the Azumino Art Line

IIDA-KAN was delivered on April 2, 2002. It opened on May 25 due to the preparation of exhibits.

The collection of the museum included more than 120 works of Yoshikuni Iida. After its opening, about a year passed without any special promotional activities. During that period, there were so many visitors that they needed to print additional copies of the brochure. It was a year of amazement with a strong following of fans of Yoshikuni Iida and high interest in the architecture designed by Fumihiko Maki.

Later, HDSI applied for an addition to the Azumino Art Line as a way to contribute to the local community as a local art and culture facility. The Azumino Art Line is a network of museums and galleries scattered over the base of the Northern Alps. Its mission is to develop culture and art in the community by encouraging tourism and attracting visitors to Azumino.

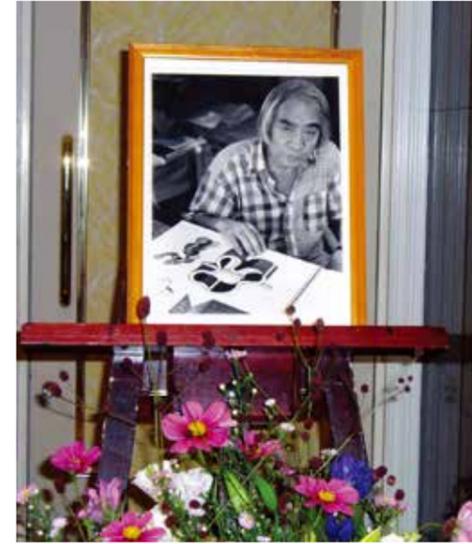
IIDA-KAN was approved at the general meeting of the Azumino Art Line Promotion Council held on May 29,



Yoshikuni Iida giving a speech



IIDA-KAN bustling with visitors



Gathering in memory of Yoshikuni Iida



President Ito giving a speech at the gathering

2003, becoming part of the local art and culture facilities.

The name was changed to “TRIAD IIDA-KAN” in July 2018. At the same time, the management was taken over by the Harmonic Ito Foundation. It still attracts many visitors as one of the art museums of the Azumino Art Line.

#### Gathering in Memory of Yoshikuni Iida

Meanwhile, a sad event took place. Yoshikuni Iida passed away suddenly in the late afternoon of April 19, 2006. He was 82 years old. On April 21, his remains were brought to IIDA-KAN before the cremation, and spent some time in front of his sculpture. The weather was strange on that day. The sky cleared up abruptly after slanting snow falling on the cherry trees in full bloom.

On September 30 of that year, a gathering in memory of Yoshikuni Iida was held at a hotel in Machida, Tokyo, where he resided. One hundred and thirty four of his friends attended the gathering, of which five gave speeches representing them, including Fumihiko Maki, an architect; Joichi Ishizaka, mayor of Machida City; Shirohei Hashimoto, former Supreme Court justice; Tetsuro Murata, director of Machida City Museum of Graphic Arts; and Mitsumasa Ito, president of HDSI.

President Mitsumasa Ito said, “It was by sheer luck that

I met him in my life. I am profoundly grateful for the 43 years I spent with him.” On that day, an exhibition titled “Yoshikuni Iida: Prints and Sculptures” was held at Machida City Museum of Graphic Arts.

### 5-8 | Introduction of the Executive Officer System

#### Start of the Executive Officer System

As of the end of March 2003, 3.3% of the shares of HDSI were held by foreign investors. As the Japanese economy was opened up internationally, the stock prices of Japanese companies started to be greatly affected by the moves of foreign investors. As part of the Program for Promoting Securities Markets Reform, the Financial Services Agency required listed companies to actively disclose their corporate governance information to establish securities markets in which investors could invest with confidence.

Against this background, HDSI resolved to adopt a new corporate governance structure with auditors at the general shareholders’ meeting held in June 2003. In addition, the newly appointed president, Nobuo Kumagai, introduced the executive officer system as part of the new corporate governance structure.

The previous Board of Directors had all the functions



President Nobuo Kumagai

including business execution. After the introduction of the executive officer system, the Board of Directors was positioned as a “strategy formulation and decision-making body and supervising body” so that it could focus on its original roles of management decision-making and supervision. The business execution function was delegated to executive officers selected by the Board of Directors. With the power delegated by the president, the executive officers executed the operations of their respective areas based on the business strategies determined by the Board of Directors to assist the president. The titles and their roles in the executive officer system are as follows.

- **The CCO (chief compliance officer) assists the management supervision function, assesses the internal control of the execution body, and conducts operational and accounting audits.**

- **The executive officer of each operation executes the operations under the COO (chief operating officer) with the power delegated by the CEO (chief executive officer).**

After the introduction of the executive officer system, HDSI strove for efficient management of the company based on quick decision-making on the management side and proper and flexible business operation on the execution side with significant power delegated. In addition,

clearer performance evaluation was expected because of the clearer boundary between the supervisor and supervisee, which was previously unclear.

#### Introduction of the Outside Director System

In 2003, HDSI introduced the outside director system, which was rare at the time. Based on the belief that a global perspective was required in corporate management, HDSI introduced the outside director system to incorporate the knowledge and experience of outsiders.

HDSI asked the business partners and banks to select outside directors and appointed individuals with rich experience and insight regarding corporate management. Today, they conduct their management supervision function independent from the executive officers.

#### Establishment of an Internal Control System

In this period, internal control systems gained in importance. After the beginning of the 2000s, frequent accounting fraud and corporate malfeasance by prominent companies in Japan and abroad became recognized as social problems, reaffirming the significance of corporate governance. This caused a global trend of legislation to strengthen internal controls, requiring the introduction of common rules.



Selected as one of the stocks comprising the J-Stock Index  
(from left to right: President Kumagai and Chairman Ito)

The objectives of an internal control system, which are the basis of corporate governance, include: 1. To ensure operational effectiveness (correct direction) and efficiency (low cost) in business execution to achieve business objectives; 2. To ensure compliance with laws and regulations, ethics, and codes of conduct in the corporate culture; and 3. To ensure reliable financial reporting. It was important to maximize the corporate value and ensure continuity through the streamlining of operations while making them rock solid.

HDSI embarked on the strengthening of its internal controls in 2006. The new Companies Act, which was to take effect in May 2006, required large companies (stock companies with capital of 500 million yen or more, which HDSI falls into) to build internal control systems as systems to ensure the properness of operations and systems to ensure effective auditing by auditors, and disclose such systems in business reports.

HDSI launched the project to deal with it on January 12 to start the establishment of an internal control system. The target domains of the internal control system included compliance with laws and regulations, control of financial processes, and control of IT, all of which had already been implemented. In April 2004, HDSI established its Charter of Corporate Behavior, and established

the “Harmonic Drive Systems Inc. Code of Conduct,” which was a guide for putting the Charter of Corporate Behavior into practice, to enforce corporate ethics for all the employees. HDSI decided to restructure them in this project to establish a control system similar to the ISO environmental and quality management systems. Their goal was to implement the PDCA cycle for internal controls.

During the first half of the project, they mainly created manuals in specialized working groups. Later, they deployed the system in the entire company and group companies. They built the internal control system of HDSI in steps, including testing and assessment of the effectiveness, start of its operation, internal auditing, and preparation and publishing of the external audit and internal control assessment report for fiscal 2008.

### 5-9 Selection of HDSI's Stock as One of the Stocks Comprising the JASDAQ J-Stock Index

#### Selection as One of the Stocks Comprising the J-Stock Index

The stock of HDSI traded on the JASDAQ OTC market was selected as one of the stocks comprising the J-Stock Index on August 2, 2004. As a result, HDSI became one



Lecture by Kazutoshi Kamijoh (manager in charge of investor relations)



Awarded the "2005 IR Company of Excellence"

of the constituents of the J-Stock Index, and the stock was listed in the J-Stock section in newspapers, rather than in the Machinery section as before.

An index is used to indicate the trend of the entire market. The J-Stock Index consists of representative stocks with high market capitalization that are actively traded on the JASDAQ market. Among over 900 stocks listed on JASDAQ at the time, the J-Stock Index consisted of 84 stocks, including HDSI. The stock of HDSI was selected as one of the major stocks representing JASDAQ. The selection was expected to attract increasing attention of investors.

As JASDAQ was licensed as a securities exchange in 2004, HDSI got listed on the JASDAQ Securities Exchange in December of that year.

On September 16, 2005, HDSI was awarded the "2005 IR Company of Excellence" by the JASDAQ Securities Exchange as a company engaging in excellent IR (investor relations) activities. This award was created in April 2004 when the companies listed on JASDAQ were required to conduct IR activities and given out based on the efforts in IR activities. It was an honor to be awarded in the first year.

HDSI was highly evaluated in terms of the following:

- **Holding factory tours for shareholders in addition to**



HD Systems, Inc. (1993)

**Presentations on Business Results (interim and year end) Having pages on the website to explain the principles in an easy-to-understand manner**

- **Using the expression "precision speed reducers," the generic term for its flagship products, in the title of the website for easier understanding**

- **Having a page on the website that summarized its internal control efforts to provide sufficient qualitative information**

On October 7, after the award was given, Kazutoshi Kamijoh, manager in charge of investor relations, gave an hour-long presentation titled "The IR Activities of HDSI" requested by the JASDAQ Securities Exchange. About 100 people including IR managers of companies listed on JASDAQ attended and watched his presentation attentively. He received a lot of questions from the audience afterward.

### 5-10 | Establishment of Harmonic Drive L.L.C. in the United States

Back in 1987, HDSI established HD Systems, Inc. (hereafter called HDSys) as a U.S. subsidiary in New York. Until then, sales in the North American market had been done indirectly through USM. As the types of HarmonicDrive® sold were limited, the sales volume accounted



Harmonic Drive Technologies Nabtesco, Inc.



Harmonic Drive L.L.C. (2007)

for only 1 to 2% of the sales of HDSI. HDSI established HDSys to directly develop new markets in North America and increase the sales volume by boosting engineering services.

On another front, the production of HarmonicDrive® in the United States by Emhart was taken over by Teijin Seiki Co. Ltd. (currently Nabtesco Corporation) and performed by Harmonic Drive Technologies Nabtesco, Inc. (hereafter called HDTN). These two companies were involved in HarmonicDrive® business in the United States, but the market was modest in size.

However, as a result of changes in the North American market, greater demand was expected in the aerospace and other advanced technology industries. Against this background, HDSI and Nabtesco decided to jointly establish a new company and develop the HarmonicDrive® business in the United States to develop new markets in North America and promote efficient and flexible

business development.

After reaching a basic agreement in September 2005, HDSI and Nabtesco established Harmonic Drive L.L.C. (hereafter called HDLLC) as a 51/49 joint venture with capital of 6 million dollars in December. Its business domain included development, manufacturing, and sales of HarmonicDrive® and related products. As HDSI invested through HDSys, HDSys remains as one of the investing companies.

HDLLC took over the HarmonicDrive® manufacturing factory and 70 workers of HDTN in a suburb of Boston, MA, as well as the sales site and 20 workers of HDSys, starting as a new company with a total of 90 employees and 2.6 billion yen in annual sales. The company started to operate in January 2006, developing new markets in advanced industries in the U.S., including the aerospace, medical, and semiconductor industries.

# Chapter 6: Stabilization

## Established Reputation and Challenges to Further Development

# 2007–2013

### 6-1 Capital and Business Alliance with Winbel Corporation

#### Seeking a Way to Expand the Mechatronics Business

In the Medium-Term Business Plan (fiscal 2006 to 2008), the HDSI Group aimed at further development by providing “Total Motion Control” without being limited to the precision speed reducer business alone. HDSI focused especially on the expansion of the mechatronics business based on the development of high-value-added actuators.

The Mechatronics Division aimed to become a leading manufacturer in an area that was more advanced and specialized than the competitors. To this end, customization capabilities and the development of actuators that only HDSI could realize were essential. In addition, HDSI felt the necessity to work on a variety of new projects, manufacture prototypes in a short period of time, and deliver them to the customer.

#### Details of the Alliance with Winbel Corporation

As a measure to execute this strategy, HDSI decided to form a business alliance with Winbel Corporation to strengthen the collaborative relationship.

The primary business domain of the company included commissioned work related to the development and mass production support of magnetic application equipment. Their strengths were in the development and design of various motors essential for the development of actuators. With talented engineers, the company had built a strong track record, and had many characteristics such as its high speed of development of motors. The connection with HDSI was formed around 2004. At the time, the mainstream in development was to meet the requirements of each customer. During that period, HDSI was focusing on application products of flat actuators. Against this background, HDSI concluded that the technologi-



Capital and business alliance with Winbel Corporation (President Kumagai and President Nakamura of Winbel Corporation)



Ground-breaking ceremony for the construction of the new factory of Winbel Corporation



Completion ceremony for the new factory of Winbel Corporation



cal capabilities of Winbel Corporation would provide an effective way to achieve quick development. First, HDSI commissioned the design and prototyping of special products including motors for tool sharpening and AC servo motors for welding guns. Later, HDSI commissioned the design, calculation, creation of drawings, and prototyping of special motors based on HDSI's specifications, deepening the trusting relationship between the two companies. HDSI decided to form a business alliance with Winbel Corporation for development and prototyping as well as the accumulation of technologies in the HDSI Group.

An outline of the business alliance is as follows:

**(1) Collaboration in the development of various motors**

**The existing collaborative relationship including the commissioning of the development, design, and prototyping of motors was strengthened to build a framework for developing high-value-added products meeting demand from customers in a shorter period of time.**

**(2) Collaboration in the manufacturing of various motors**

**The expertise on manufacturing, material pro-**

**urement, and quality assurance related to motors was shared to build a collaborative relationship in terms of manufacturing.**

Along with the business alliance, HDSI also decided to form a capital alliance to strengthen the relationship between the two companies for mutual future development.

The business and capital alliance agreement was signed on May 16, 2007. The capital alliance was implemented by underwriting the third-party allocation of shares by Winbel Corporation to provide the funding needed to expand its business. As a result, HDSI became an owner of 50% of the shares issued by Winbel Corporation, making it a consolidated subsidiary of HDSI.

#### Construction of the New Factory

After that, HDSI decided to build a factory as a new production base. As a result of comparing candidate sites in Komagane with the adjacent area of Winbel Corporation in mind as the first candidate, HDSI concluded that the adjacent area was the best choice based on the conditions such as infrastructure development, investment, the existing factory becoming dormant due to relocation, and



A bird's-eye view (upper left), interior (upper right), and cafeteria (lower left) of the HPI factory after extension

early start of operation. In May 2007, HDSI acquired the land of 2,340.25 m<sup>2</sup>. After the ground-breaking ceremony on August 17, the construction of the factory was completed in January 2008. After a factory tour of the new factory, a completion ceremony, and a party at Komagane Kogen Resort Linx on February 6, the factory became fully operational.

## 6-2 Acquisition of 100% Ownership of HPI

### Acquisition of Shares

One of the essential components of the actuators and unit products of HDSI was cross roller bearings (hereafter called CRB). HPI had been manufacturing CRB in collaboration with Akahane KOKI. On June 20, 2007, HDSI acquired all the shares of HPI owned by Akahane KOKI. As a result, the proportion of voting rights in HPI held by HDSI became 100%.

### Extension of the Factory

HPI started the extension of the factory. It was completed on July 18, 2008. As a result of adding a total of 1,411 m<sup>2</sup> (1,076 m<sup>2</sup> on the first floor and 335 m<sup>2</sup> on the sec-

ond floor), the total area became 2,887 m<sup>2</sup>, which was an increase by a factor of 1.87. After the extension, the first floor had the factory area, office, meeting rooms, and entrance, and the second floor had a new cafeteria where all the employees could have lunch together. The extended factory area was divided into two halves, one area for heat treatment and another area for blanking machines.

## 6-3 Capital and Business Alliance with Ome Iron Casting Co., Ltd.

### Background of the Alliance

In this period, HDSI also worked on forming a new alliance with Ome Iron Casting Co., Ltd. The relationship between HDSI and Ome Iron Casting started when a problem of wear of the gear teeth of a circular spline occurred.

As a result of searching for a high-hardness material with high wear resistance to resolve the problem, HDSI found the spheroidal graphite cast iron FCD800 manufactured by a company in Inuyama, Aichi. The material had satisfactory performance and helped solve the problem of wear. However, in the late 1980s, the company manufacturing FCD800 pulled out. As a result of con-



Capital and business alliance with Ome Iron Casting Co., Ltd. (President Sasahara and President Miyoshi of Ome Iron Casting)



Exterior view of the factory of Ome Iron Casting Co., Ltd. around 2008



Recent exterior view of the factory (2019)

sulting with the material trading company, Ome Iron Casting was introduced to HDSI.

Ome Iron Casting was a manufacturer of cast iron parts with strength in technical development and manufacturing related to high-hardness cast iron. Later, the high-hardness cast iron materials of the company became essential for the production of HarmonicDrive<sup>®</sup> and AccuDrive<sup>®</sup>.

While the two companies were building and maintaining a good business relationship over years, different types of mechanical equipment adopting the actuators and precision speed reducers of HDSI, such as industrial robots and semiconductor manufacturing equipment, kept on evolving, resulting in growing demand for more lightweight and compact, higher-strength, and higher-precision products.

In addition, HDSI needed to create a competitive edge over the competitors and reduce the risk of leakage of the cast iron technology to the competitors by utilizing the technological capabilities (high-hardness cast iron materials and ability to make cost reduction proposals using cast iron) of Ome Iron Casting related to the cast iron materials affecting the performance of HDSI's products.

Against this background, HDSI resolved to sign a business and capital alliance agreement with Ome Iron Casting at the board meeting on October 20, 2008. On October 27, the two companies signed the business and capital alliance agreement and share transfer agreement.

### Outline of the Alliance

The details of the business alliance are as follows:

- (1) Increase in trade of cast iron members for precision speed reducers with emphasis on high-hardness cast iron materials
- (2) Deepening and expansion of the collaborative relationship in product development
- (3) Promotion of joint research on cast iron materials and collaboration in intellectual property-related activities
- (4) Business alliance related to quality assurance systems

In terms of the capital alliance, another pillar of the alliance, HDSI acquired 3,000 shares from the existing shareholders of Ome Iron Casting. At the same time, HDSI underwrote an issue of 2,820 shares in the form of underwriting the third-party allocation of shares by Ome



Capital and business alliance with Soft Servo Systems, Inc.

Iron Casting to provide the funding needed to expand its business and develop its infrastructure. As a result, HDSI became an owner of 49.2% of the shares issued by Ome Iron Casting.

#### 6-4 Capital and Business Alliance with Soft Servo Systems, Inc.

##### Impetus for the Alliance

HDSI adopted Total Motion Control, consisting of six elements, speed reducers, motors, drivers, controllers, sensors, and other system elements, as its business domain, and focused on mechatronics products. However, HDSI had the weakness that it didn't have sufficient proprietary technology and human resources related to controllers, i.e., devices for controlling the motion of actuators, etc.

Against this background, HDSI resolved to form a business and capital alliance with Soft Servo Systems, Inc. (hereafter called SSJ), which had advanced technology, at the board meeting on December 9, 2008.

At the time, Soft Servo Systems, Inc. (hereafter called SSA), the U.S. subsidiary of SSJ, had acquired key technology. They had successfully commercialized the unique PC-based controller technology developed by MIT (Mas-

sachusetts Institute of Technology). SSJ was planning a business development worth about 1 trillion yen in the global motion control market centering on SSA products, and looking for companies willing to participate in the capital increase.

HDSI concluded that it could achieve expansive collaboration with SSJ that could be complementary to each other. Specifically, such a collaborative relationship would include creating and promoting joint sales strategies taking advantage of the characteristics of each other's products, providing motion control systems that matched the needs of customers, and mutually giving advice on new products developed by the two companies.

##### Signing of the Agreement and Withdrawal

The agreement was signed on December 26, 2008. The capital alliance was implemented by underwriting the third-party allocation of shares by SSJ and providing short-term and long-term financing to provide the funding needed to expand its business.

After starting joint sales activities such as participating in exhibitions and visiting customers after the signing of the agreement, HDSI faced unexpected problems.



At the award ceremony of the Order of Merit of the Federal Republic Germany in the Grade of the Cross  
(From left to right) Wife of Chairman Ito, Chairman Ito, German ambassador Daerr, and Teru Miyamoto (proposing a toast)



(From left to right) Chairman Ito, former President Hasegawa, and President Sasahara

For example, there was a feeling of hesitation in leaving the core high-level controller technology to a small-sized company. At other times, the degree of perfection and marketability of SSJ's controllers were questioned. Due to a drop in performance of SSJ on top of all that, HDSI decided to cancel the alliance. In March 2011, HDSI gave SSJ notice of the termination of technical development and sales activity, and completely withdrew in summer.

#### 6-5 Chairperson Mitsumasa Ito Received the Order of Merit of the Federal Republic Germany in the Grade of the Cross

On December 3, 2008, Chairperson Mitsumasa Ito (appointed as chairperson and representative director in June 2003) received the Order of Merit of the Federal Republic Germany in the Grade of the Cross from Hans-Joachim Daerr, German ambassador to Japan, by authority of the federal president of the Federal Republic of Germany at the Embassy of Germany. It is awarded for special merits for the Federal Republic of Germany.

It was awarded to Chairperson Mitsumasa Ito for his contribution as a bridge between Japan and Germany in terms of both business and culture, such as participating in the establishment of, and acting as a director of, the

Heinrich Hoffmann Society established in honor of the achievements of the psychiatrist born in Frankfurt.

#### 6-6 Strengthening of the Development and Production Systems

##### Start of Business with Foxconn and Samsung Electronics

Around 2006, HDSI received an order from Foxconn in China, stating that they wanted the same Harmonic Drive® as in drawings for a Japanese robot manufacturer. However, HDSI instituted a policy of not providing something designed for a customer to another customer. Assuming that a company that obtained drawings of another company to place an order would not have much in the way of technological capabilities, HDSI decided to decline the order and visited their factory in Shenzhen.

Contrary to expectations, the factory was huge, with different buildings manufacturing smartphones, gaming machines, and music players. Foxconn was an EMS company manufacturing products for well-known manufacturers. There were dormitories and restaurants, like a city, on the factory premises. About 300,000 employees were working at the Shenzhen factory alone.

Feeling ashamed for the lack of knowledge, the HDSI staff was shown a prototype robot being developed in-house, which used standard products of HarmonicDrive®. The design was a little old, but it was their own original design rather than just copying another's design. And it was little wonder because there was a famous engineer involved who had been doing research on robots while working at GM Fanuc after graduating from Massachusetts Institute of Technology. The engineer seemed to have been told by his Chairman Terry Gou to build automated lines for the company to replace as many workers as possible with robots so that more inexpensive and better products could be produced, from the viewpoint of promoting labor-saving in worker development and workforce management as well as achieving quality stability.

Despite visiting Foxconn to decline the order, HDSI ended up starting business with the knowledge that the company had sufficient knowledge of robots, technological capabilities, and a large market.

After that, HDSI started delivering special HarmonicDrive® units for Foxconn designed as requested. Despite the twists and turns such as receiving a major order for the release of a new model of smartphone and receiving

no order due to the 2008 financial crisis, the company is becoming a stable business partner.

Around that time, HDSI also started business with Samsung Electronics. Samsung Electronics at the time was not as large as it is now. It just started developing robots by copying the robots manufactured by Japanese manufacturers.

One day, HDSI received a request for an immediate visit from Samsung Electronics, saying HarmonicDrive® was producing noise and seemed faulty. An engineer of HDSI visited the company thinking that it could be caused by peripheral equipment. After checking, the engineer confirmed that HarmonicDrive® was generating abnormal noise. As a result of investigating the cause, the engineer found that the sliding surface was scratched due to the wrong assembly of the bearings, which generated abnormal noise.

HDSI apologized and admitted that it was caused by an error it made, and offered to recall and replace all the delivered units. They were impressed by this offer, saying that they had never seen any Japanese company that admitted their mistakes. As a result of this incident, they started to appreciate how HDSI treated them. The two

companies built a deeper trusting relationship, and eventually started to look for solutions jointly when a problem occurred in robots developed by Samsung Electronics.

For example, a problem occurred in which a robot transferring liquid crystal panels produced dust. As a result of analyzing the airflow on a supercomputer, HarmonicDrive® was initially suspected. However, an examination of the drawings indicated that it was caused by the timing belt linking the motor and HarmonicDrive®. The timing belt was made of rubber and had teeth on it, and produced rubber dust when the temperature rose during operation. As a result, no sealing was achieved even though the cover was placed. Working together to solve problems including ones attributable to portions other than HarmonicDrive® further deepened the trusting relationship.

The engineer at Samsung Electronics acting as a contact person since the beginning of the business, who has advanced in the company, highly values the relationship with HDSI even today. In order to grow business, being earnest and developing trusting relationships are critical.

#### **Establishment of the Three-Site Development System**

While successfully finding major business partners, the factory in Japan and two factories overseas (Harmonic Drive System GmbH in Germany and Harmonic Drive L.L.C. in the United States) decided to enhance the partnerships for development, etc. in June 2009. The three sites were to develop new products to be sold globally through technological exchange between each other.

#### **Transition to the Functional Division System**

Due to the sudden changes in the market caused by the 2008 financial crisis, HDSI experienced unprecedented sudden market changes and fluctuations in the period from the year end of 2008 to the first half of 2009. In these circumstances, HDSI concluded that it was important to directly face such market changes and fluctuations and deal with them promptly to fulfill its duties.

In the Medium-Term Business Plan (fiscal 2009 to 2011) at the time, the priority objectives included shorter delivery time, expansion of the mechatronics business, further development of world-leading precision speed reducers, and development of new markets. HDSI con-



President Masakatsu Sasahara

cluded that, in order to achieve these objectives and go through the drastically changing economic circumstances by better utilizing the management resources, it would be effective to convert the existing organizations vertically divided by product family (i.e., product divisions) into organizations by function such as production and development (i.e., the Production Division and the Development Division). On October 1, 2009, President Masakatsu Sasahara implemented the following organizational changes:

#### (1) Creation of the Production Division

**The Production Division consisted of the HD Production Departments and MT Production Department. It was decided to maximize specialties by concentrating production-related specialized resources and boost production innovation under these roles in a responsible manner.**

#### (2) Creation of the Development Division

**The Development Division, consisting of the HD Development Department, MT Development, and Motor Development, was created. It was decided to concentrate specialized capabilities related to developed technologies and accelerate the market intro-**

**duction of new products by improving development capabilities through the regular mutual interaction of mechanical, electrical, and electronic expertise.**

In addition, the Applied Technology Department of the HD Division and the Engineering Design Department of the MT Division were integrated into the Applied Design Department in the MC Business Development Division. The department was created to complete the entire process from negotiation to design for new inquiries within the Sales Division. HDSI aimed to develop new applications and increase customers by improving response to customers.

#### Full-Scale Introduction of the 3D CAD System

Along with the strengthening of the organizational structure, HDSI had to introduce new tools. At the top of the list was the 3D CAD system.

HDSI mainly offered build-to-order manufacturing, mostly with special designs based on the standard products. Its design method was unique, i.e., designing based on the customer's requirements. Because many customers were in the process of designing the device in which HarmonicDrive® was to be embedded, the individual



Training sessions for the introduction of the 3D CAD system



requirements and specifications were changed regularly. In addition, one of the challenges was to complete the design in a short period of time while maintaining high quality, because any defect in design could cause defective products to be manufactured.

HDSI looked at the 3D CAD system as a way to resolve this challenge. HDSI decided to introduce it on February 15, 2001, and introduced the model called UG (Unigraphics, currently NX) to the Development Departments.

At the time, UG was the top-of-the-line in terms of features, and its reputation as a design tool was unquestionable. However, HDSI started by introducing it partially. This was because of the extremely high introduction cost as well as the decision that a learning period was required to avoid the risk of stalling of on-site operations caused by the switching.

After the system was actually put into operation, training and acquisition of proficiency took many hours as expected. The system was not linked with the PDM system and used only as a drawing system. The departments involved in design-to-order/production design and production engineering did not feel the effect of the intro-

duction. Because the conventional 2D CAD system could be used in the operations without any problem, the users in the departments using the CAD systems were allowed to freely choose from the 2D and 3D systems. As a result, the system had not taken root after about 10 years.

Nonetheless, in 2009, HDSI switched to the 3D CAD system company-wide, and upgraded the NX. This caused a problem because the new system was not compatible with the existing data. There also were problems in terms of applications specific to HDSI, such as simulation of the meshing of the gear teeth of HarmonicDrive®. Because the NX was a high-end model intended for the automobile and aerospace industries, no interface software was publicly available. It turned out that HDSI could not add functions in-house and had to ask the support provider to create one as needed. This posed a risk of leakage of HDSI's proprietary design expertise.

Despite these problems, the introduction of the 3D CAD system was essential to shorten the development period and promote more efficient design operations. As an introduction policy, HDSI decided to clearly specify the expected effects, implement the methodology, calculate the cost performance, and implement full-scale



Ground-breaking ceremony for the extension of the Hotaka Factory



Completion ceremony for the extension of the Hotaka Factory



Main entrance after the extension

switching in a reasonably short period of time. As a result of re-evaluating the commercially available 3D CAD models, HDSI selected SOLIDWORKS.

Because of its user-friendliness, SOLIDWORKS was widely used mainly in the general industry sector and had a dominant share at the time. It offered advantages in data exchange with customers and business partners, making it a better option than the NX on practical side.

After introducing it in 2010, HDSI took about one year to prepare the basic rules, settings, and screws under a project structure. At the same time, the departments started operating the system in turn, although on a trial basis. The Research and Development Departments started operating the system in October after conducting operational training from August and September under the policy of using the 3D system for new projects. The Design-to-Order and Production Engineering Departments started operating it by switching in phases by product family in February 2011, after conducting operational training, making the PDM system compatible with 3D data, and developing macros for streamlining design from August to December and conducting operational verification testing in January 2011.

However, the switching process did not go smoothly. After about one year, problems started to surface, such as not being able to make drawings as before (i.e., 2D), and special design taking enormous time in the Design Department unless there was a complete set of basic components.

Later, as a result of forming an operation preparation group to trace the 2D drawings of the standard products over about one and a half years, the operation preparation for the standard products was improved quickly. The problem of not being able to make drawings as in the previous 2D drawings was resolved. However, a problem of modeling was found when a common design was tested. This problem was resolved when the experts in design built a master demo compatible with all the components of the standard products with common designs in mind. Simultaneously, HDSI introduced file management software for 3D CAD data and conducted CAD operation training relevant to its products. After a process of trial and error, HDSI achieved full-scale operation of the 3D CAD system in 2014, which was long overdue.



Factory layout plan



Addition to the Hotaka Factory (East wing)



Addition to the Hotaka Factory (West wing)

#### Extension of the Hotaka Factory

To deal with the sudden demand fluctuations that occurred after the 2008 financial crisis, HDSI decided to increase the production capacity of the Hotaka Factory by 1.8 billion yen monthly, or 25%, and extend the factory as part of the efforts. The plan was to build a one-story steel frame building with a basement floor (partially RC, including the machinery room on the basement floor) with a total area of 1,264.50 m<sup>2</sup> using the visitor parking area on the east side, and a two-story steel frame building with a total area of 1,516.72 m<sup>2</sup> using the parking area for company cars and visitors' cars on the west side. In addition to the extension, HDSI decided to work on a renovation plan (air conditioning and electrical facilities) because the existing factory was about 20 years old.

On October 22, 2010, a ground-breaking ceremony was held with the parties concerned at the site planned for the extension. The construction was conducted carefully by the contractor because the existing production factory was kept operational during the construction.

The construction was completed in April 2011. HDSI held a completion ceremony on May 19. In addition, the renovation of the south side and repairs of the exterior

of the existing building were conducted. The entire work was completed at the end of June.

The expansion of the factory area was not the only objective of the extension of the Hotaka Factory. The objectives of this work included devising a system allowing for an efficient production increase without increasing production personnel and building new production lines by introducing more than 40 units of new production equipment.

After mid-March when the work was nearly completed, it became difficult to obtain building materials and introduce equipment due to the effect of the Great East Japan Earthquake. Despite the difficulties, the factory became operational as planned with the support of many employees who helped transfer equipment and create new lines while sticking to the daily production schedule by giving up their holidays, in addition to the valuable efforts of the construction personnel and equipment suppliers.

It is worth mentioning that four chestnut trees were transplanted along with the construction work. As can be seen from the fact that an archaeological site was found at the building site of the Hotaka Factory, there were indigenous people living there for many years. Valuing the idea



Introducing the members



President Sasahara giving a speech



Building where HDCH is located (Shanghai)



Founding members of HDCH From left to right: Wu, Senior Sales Manager Zhang, President and CEO Maruyama, and Wei

that HDSI was temporarily allowed to use land with a long tradition, HDSI had been cautioning itself not to fell native trees on the premises.

Upon the extension of the factory, a problem arose as to how to deal with the four chestnut trees growing wild on the site planned for construction. While the idea of felling the trees was on the table, Chairman Mitsumasa Ito decided to transplant them, and all of the four trees were transplanted without being felled. These trees have survived to this day, creating deep shade.

## 6-7 Establishment of the Sales Subsidiary in China

### Ever-Expanding Chinese Market

Many companies from around the world, including Japanese, European, and American companies, started to establish their production bases for automobiles, mobile phones, and liquid crystal panels in China. China was indeed the “factory of the world.” Consequently, many industrial robots were in use, giving a big business opportunity to HDSI’s products. In China, businesses had been growing centered around industrial robots. In addition, new industries related to liquid crystals, semiconductors,

machine tools, and electronics were becoming growing industries, and their further growth was expected.

On top of that, the Chinese government was promoting domestic production in many industries, one of which was the robot industry. Based on the “863 Program” adopted by the Chinese government in March 1986, the domestic production of robots and their major components was promoted. The program encouraged universities and research institutes to conduct research on basic technologies and private companies to reach commercialization and develop applied technologies under the lead of the central and local governments. It was equivalent to the industry-academia-government collaboration project in Japan.

### Establishment of the Local Sales Subsidiary

In the promising Chinese market, HDSI had been conducting sales activities mainly through the distributors. Based on the conclusion that it would be desirable to establish a site in China to expand sales and boost technical services, HDSI decided to establish a sales subsidiary.

After resolving to establish a sales subsidiary in China at the board meeting on September 17, 2010, HDSI pro-

ceeded with the establishment of a new company. On January 11, 2011, HDSI established Harmonic Drive Systems (Shanghai) Co., Ltd. (hereafter called HDCH) in Shanghai Waigaoqiao Free Trade Zone with capital of 100 million Japanese yen as a wholly owned company of HDSI.

After a party celebrating the founding on March 3, HDCH officially started to operate. HDCH first focused on expanding the sales of mechatronics products. HDCH conducted sales activities in cooperation with local distributors. They worked on building relationships with research institutes including universities, because in China, the technical development objectives defined as government policies were to be implemented through industry-university partnership.

Around the time of starting its operation, HDCH received many inquiries from Japanese users operating there and peers as well as universities and research institutes. While developing new markets on a full scale by developing its distributors, HDCH accumulated customer information and gained a better understanding of the technological levels and potential demand of different industries, areas with a high concentration of prospective

customers, and activities of the servo market and competing manufacturers. HDCH analyzed the information and kept revising its sales strategies.

The main market that HDCH initially targeted was the emerging robot manufacturers that were growing in China at the time. On top of that, a variety of Chinese-made robots were exhibited at the Expo 2010 Shanghai China, which ignited a robot boom. In addition to the automobile industry, the electronic component industry started attracting attention as a new robot market. As the “863 Program” described earlier gradually became widespread and developed, Chinese robot manufacturers and component manufacturers were consistently growing. Many EMS companies expanding into China, adoption of a large number of robots including one’s own, and elevated labor costs and shortages of human resources progressing gradually heightened the momentum toward the promotion of automation and robotization. In addition to the electronic component industry, the target industries included manufacturers of home appliances, pharmaceuticals, beauty products, and miscellaneous goods. In the promising business environment, HDCH aimed to become an information distribution hub while closely



The 28th Harmonic Concert



"My Flying House Robot" by Juran Maruyama

Harmonic Concert commemorating the 40th anniversary  
Mitsuko Shirai (mezzo-soprano) and Hartmut Höll (piano) recital

Public exhibition

watching the market trends in China.

## 6-8 Celebration of the 40th Anniversary

### Harmonic Concert Celebrating the Anniversary

In 2010, HDSI celebrated the 40th anniversary and held a number of events celebrating the anniversary.

HDSI held the 28th concert of the Harmonic Concert Series, which had taken root locally, as the Special Concert Commemorating the 40th Anniversary on October 2. The audience enjoyed the performance of Mitsuko Shirai (mezzo-soprano) and Hartmut Höll (piano).

### Special Exhibition at IIDA-KAN

At IIDA-KAN, HDSI held a special exhibition celebrating the 40th anniversary "TRIAD Yoshikuni Iida and Fumihiko Maki Joint Exhibit" for a period of one year from November 3. The exhibits included "SCREEN-CANYON" in the sculpture exhibit hall, a set of three sculptures "Werk Spiegel" (1969) on the wooden deck,

and a new bronze sculpture molded from Yoshikuni Iida's wooden sculpture "Hito- (Bird/Human)" (1961) on the grass mound.

In the painting exhibit hall, two scale models and one panel of Fumihiko Maki's "TRIAD" (2002), and one scale model and four photo panels of his "Kaze-no-oka Sosaijo" (1996) (Nakatsu, Oita Prefecture) were displayed. In addition, five photo panels introducing their collaborative work, in which Fumihiko Maki designed the building and Yoshikuni Iida created the mobile sculpture decorating the building, were displayed. Yoshikuni Iida's paintings, including 11 watercolor paintings and drawings of his boyhood days, six sketches of the war fronts in China, and oil and collage on canvas "Orchestra" (1952) were displayed, including the letters from Ryuzaburo Umehara, Chimei Hamada, and Masuo Ikeda in the exhibition case.

### Art Contest "My Kind of Robot"

HDSI also held an art contest celebrating the 40th anni-



Party to celebrate the 40th anniversary



versary titled "My Kind of Robot." The art contest was open to sixth graders in Azumino City, and received 354 entries from seven schools, which was more than expected. On November 6, HDSI held an award ceremony and a public exhibition of the entries. The entries were also displayed in the cafeteria and the hallway in front of the locker rooms of the Hotaka Factory.

### Party to Celebrate the 40th Anniversary

On November 12, HDSI held a party to celebrate the 40th anniversary at Hotel Buena Vista Matsumoto. About 260 employees of HDSI and group companies as well as about 200 family members of the employees attended the party, and enjoyed the food, performances such as pantomime, and entertainments for children (candy crafting and balloon arts).

## 6-9 Systemic Transformation of the Subsidiary and Establishment of SAMICK ADM CO., LTD.

### HAD Starting Its New System for Planetary Gear Business

Since spinning off and becoming independent from the Hotaka Factory in 2003, HAD integrated its functions into the Toyoshina Factory, and independently worked on the development and production of planetary gear AD products. After over eight years, its sales size had more than doubled. In addition, HAD established a new market of precision planetary speed reducers with the HPG series, one of its flagship products, which was unrivaled in the industry, and grew into a market leader and acquired a market share in Japan.

However, its business environment was changing significantly as a result of the industrial hollowing in Japan, transition to the Chinese market and other Asian markets, competing manufacturers that were catching up, and severe price competition including the effect of a strong



Establishment of ADM. Representative Director Lee (SAMICK HDS) and President Wakumoto (HDSI)



Construction of the new factory of ADM



New factory of ADM

yen. Examining each of these conditions, HAD predicted that it would no longer be able to maintain its edge relying only on the products that HAD had been developing and strategies, which had been used since the founding. This meant that it required a major change.

On another front, HDSI regarded China and other Asian countries as the most important markets to develop, and considered conducting product planning and development in an integrated manner for RD products (harmonic products), mechatronics products, as well as AccuDrive® products, and focusing on specific applications. As a result, HDSI decided to promote product planning and market development jointly with HAD as a new global strategy for the planetary speed reducer business. HDSI also decided to try to develop a new market in China and other Asian countries by making HAD specialized in production to further improve its competitiveness in terms of quality, cost, and delivery (QCD).

Against this background, HAD started its new system for the planetary speed reducer business in January 2012. HAD transferred 13 employees, mainly in the Development Department, to HDSI, as well as transferring and

integrating its development, design, CS, marketing, and general affairs/accounting operations to the corresponding departments of the Hotaka Factory. As a result, HAD became a company specialized in the production of planetary speed reducers.

#### Establishment of a Joint Venture in Korea, SAMICK ADM CO., LTD.

As described earlier, the planetary speed reducer business was facing a transition period. In the planetary speed reducer market in Japan, HDSI achieved a dominant share of the precision planetary speed reducer market as a result of introducing the high-precision, reliable HPG series.

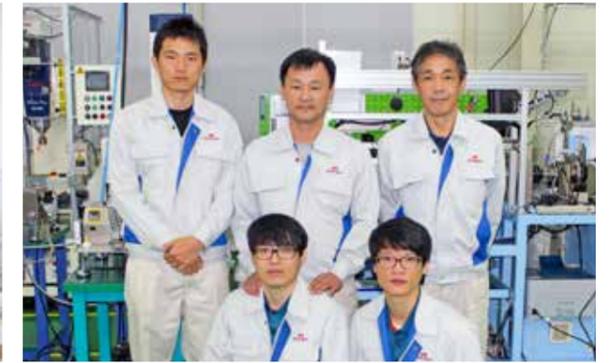
However, HDSI could not even secure a market outside Japan. In Korea, for example, general-purpose planetary speed reducers of the competitors held a dominant share of the market, and the market share of HDSI's precision planetary speed reducers including HPG was only about 15%. In other words, priority was given to price rather than precision. The situation was similar in China. In China, the planetary speed reducer market kept expand-



Members at the time of the establishment of ADM  
From left to right: Representative Director Hirabayashi, Assistant Manager Jin, Executive Director Lee, Ms. Yun, and Section Chief Choi



Machining shop



Back, from left to right: Unit Leader Choi, Team Leader Park, and Factory Manager Mimura  
Front, from left to right: Unit Leader Lee and Subsection Chief Bea



Assembly shop

ing as the servo motor market expanded even after the 2008 financial crisis. The market size was 110,000 units and 3.2 billion yen in 2003, which increased to 182,000 units and 5.2 billion yen in 2010, and finally exceeded the 10-billion-yen mark in 2012. However, in 2010, the top two competitors held a dominant share of the market, with the third competitor and below holding an incomparably lower share.

Against this background, HDSI started to consider the “expansion of the general-purpose planetary gear business into the Asian markets excluding Japan” in August 2011 to restructure the planetary gear business. The objective was to establish a market for HPG in the Korean, Chinese, European, and American markets excluding Japan as well as to establish the planetary speed reducer business of HDSI. To achieve this, HDSI first tried to bring the general-purpose planetary speed reducers designed by HDSI to the market to establish its market.

While looking for a company that would manufacture the general-purpose planetary speed reducers, HDSI focused on Korea as a country with the technological capabilities to manufacture planetary speed reducers, ease

of member procurement, and low labor cost. In Korea, there was SAMICK HDS Co., Ltd., a distributor of HDSI's products with a good business relationship and trusting relationship with HDSI developed over years in terms of marketing and sales in the Korean market. Despite some disadvantages such as limited experience in the manufacturing of planetary speed reducers and the lack of manufacturing facilities and expertise, it was expected to start up in the early stage (one to two years) with the assistance of HDSI and HAD.

After such consideration, HDSI took the first step in the expansion and development into the Asian markets. HDSI mapped out a blueprint to develop the general-purpose planetary speed reducer market jointly with SAMICK HDS Co., Ltd. in Korea to acquire a certain level of share in Korea and to enhance sales promotion of HPG.

Later, HDSI proceeded with the development of general-purpose planetary speed reducers toward the objective of achieving 40% or more of the market share (monthly production of about 3,000 units) in the Korean planetary speed reducer market. The development objec-

tives set for the development included a cost percentage of 60% or less of the current market price of the product of Company A, which had a dominant share in Korea, appearance and performance equivalent to that of Company A's product, performance including noise equivalent to or better than that of competing products, and mounting dimensions identical to and length equivalent to that of Company A's product. As a result of seeking a lower price in design based on the existing product, the HPN series was developed.

Concurrently, HDSI considered establishing a manufacturing company. As a result, HDSI resolved to establish a company manufacturing planetary speed reducers jointly with SAMICK HDS at the board meeting on February 13, 2013. On February 19, six days later, HDSI established SAMICK ADM CO., LTD. (hereafter called

ADM). HDSI invested 51% of capital of 3 billion won in ADM and provided its expertise in the manufacturing of planetary speed reducers. The factory and head office were to be located on the premises of SAMICK HDS on the outskirts of Daegu.

The factory of ADM was completed in April and started the production and shipment of the HPN series in July. SAMICK HDS exclusively handled the sales in the Korean market, and HDSI and HDCH handled the sales in China, Taiwan, and other Asian countries.

However, there were already several competitors in Korea, making ADM fight an uphill battle, in which the sale of HPN series products fell below their expectation and it could not turn positive over a long and difficult period of time.

# Chapter 7: Investment for the Future

## Opening up the Path to the Next 50 Years

# 2014–2020

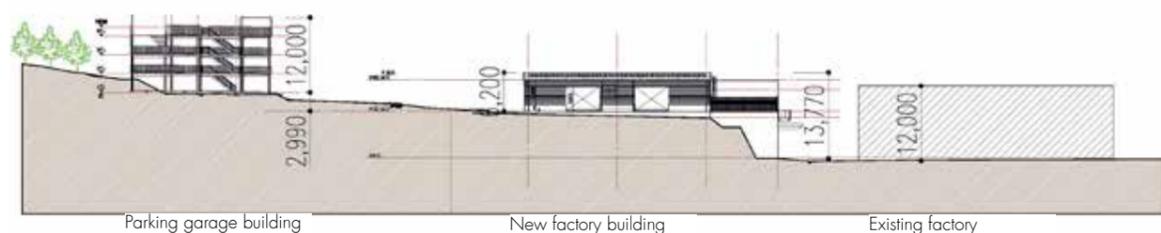
### 7-1 | Investment for Enhancing the Production Capacity for Precision Speed Reducers

#### Purposes and Outline of Capital Investments

In August 2014, the HDSI Group decided to make capital investments in the production bases such as the Hotaka Factory to enhance production capacity. The budget was a total of about 2.8 billion yen for HDSI, HPI, and HAD.



Schematic drawing of the extension of the Hotaka Factory



As the background, the production bases were operating with an increased production load as a result of the favorable economic conditions since the beginning of 2014. In November, HDSI announced an upward adjustment of consolidated earnings. The initial estimates of 24.5 billion yen in net sales and 6.4 billion yen in operating profit were adjusted to 26 billion yen in net sales and 7.35 billion yen in operating profit.

Major causes of the favorable economic conditions included steady capital investments in the manufacturing industry in the developed countries and increased need for automation and labor-saving in the emerging countries. Especially, the demand increased for Harmonic Drive® for welding robots and painting robots used in automobile production lines and small assembly robots



Industrial robots used on automobile and smartphone manufacturing floors (for illustration purposes only)

used in production lines for smartphones and tablets.

Before too long, orders exceeded the production capacity. Long overtime work and holiday work were required to compensate for the shortage. It was impossible to further increase the production capacity with the existing factory and production equipment. HDSI devised a large-scale capital investment plan to improve its competitiveness in terms of quality, delivery, and production efficiency while enhancing a stable supplying capacity to customers.

HDSI decided to invest 2 billion yen out of the budget of 2.8 billion yen in the Hotaka Factory to increase its monthly production of HarmonicDrive® by about 10,000 units to make it about 50,000 units. The breakdown was about 1 billion yen for machinery and equipment for HarmonicDrive®, and about 1 billion yen for the construction of a new factory building.

Along with the capital investment in the Hotaka Factory, HDSI planned to invest about 300 million yen in HPI producing cross roller bearings for HDSI to introduce the machinery and equipment for the manufacturing of cross roller bearings, and invest about 500 million yen in HAD producing precision planetary speed reduc-

ers to introduce the machinery and equipment for the manufacturing of precision planetary speed reducers.

#### Enhancement of the Hotaka Factory

The actual operations based on the capital investment plan were started in the summer of 2014. First, organization and relocation were conducted on the west side of the second floor to concentrate the assembly processes at the Hotaka Factory in one location to improve efficiency. As a result, the RD assembly on the first floor was relocated to the west side of the second floor in December. For part cleaning, a centralized cleaning room was created to be shared with the mechatronics assembly. In the vacant space of the first floor created by relocating the RD assembly, machine tools required for component production were installed in phases from the beginning of 2015.

HDSI also crystallized the plan for a new factory. The plan was to build a one-story SRC factory building with a basement floor with a building area of 3,226m<sup>2</sup> and a total area of 5,663m<sup>2</sup> on the west side of the existing factory. HDSI decided on adopting a half-underground structure where the factory space was in the ground to align the height of the floor surface with that of the first



Parking garage under construction



New factory under construction



New factory under construction



floor of the existing factory as the building site was on a slope.

HDSI also planned to build a steel frame parking structure (accommodating 75 cars) on the rooftop of the new factory, and a steel frame parking garage building (accommodating 230 cars on the 1st to 3rd floors, 80 cars on the rooftop) on the land on the west side.

After HDSI decided on the outline, the design firm worked on the detailed design in accordance with the grand design of the Hotaka Factory. Special emphasis was placed on the consideration of environmental loads and making the production environment appropriate for the production of the next-generation HarmonicDrive®.

At the beginning of 2015, HDSI started preparing documents for a specified development project to be submitted to Azumino City. On June 9, 2015, with its permission in sight, HDSI held a ground-breaking ceremony conducted by a Shinto priest from Hotaka Shrine in the multipurpose parking area on the west side of the factory selected as the building site. After that, the construction of the parking garage and new factory was started by the contractor. After the groundwork conducted in September and steel structure erection and roofing started in

October, the framework became visible before the arrival of winter. After that, the construction continued without cessation during the winter, and was completed at the end of March 2016. The construction of the parking garage was completed earlier at the end of November 2015.

On April 18, 2016, HDSI held a completion ceremony for the new factory building including the parking garage. During the construction process, many difficulties large and small had occurred. For example, the archaeological site of Shinbayashi was discovered under the ground of the planned site for the parking garage, and a trial excavation was conducted by Azumino City for a period of about one month before the start of the full-scale construction. Although the construction was difficult because of the leveling of the slope, it was completed as scheduled as a result of the efforts of the construction personnel.

The construction on the slope had some advantages. The resulting half-underground structure helped significantly reduce temperature changes and vibrations of floors and walls that would affect machining. Furthermore, utilization of geothermal heat helped reduce air conditioning costs and environmental loads, and the low building height helped reduce impact on the landscape.



Completed new factory (April 18, 2016)



Solar panels



Musser Heritage Room

In addition, HDSI moved ahead with the installation of solar panels (200 kwh) on the rooftop of the new factory for increased environmental friendliness. The installation was completed in October 2016, and the operation started in November. All the electricity generated is sold.

**Family Members of C. Walton Musser Visited HDSI**

While proceeding with the plan for enhancing the Hotaka Factory, HDSI experienced an incident that made it look back on the early years of the company. HDSI invited three family members of C. Walton Musser, the inventor of HarmonicDrive®, to visit HDSI, and the visit came to fruition. On September 22, 2014, they visited the Head Office in Shinagawa-ku, Tokyo. On September 23, they visited the Hotaka Factory and took a tour of the company as well as the Musser Heritage Room.

The family members visiting Japan were Mrs. Yvonne Graham, a daughter of Musser, Mr. David Graham, his grandchild, and his wife Mrs. Cheryl Graham. They were accompanied by three people including the president of Harmonic Drive L.L.C.

When HDSI built the Musser Heritage Room on the premises of the Hotaka Factory in 2006, the family mem-

bers donated Musser's belongings to HDSI as proof of being his rightful successors. All the donated items were valuable, such as Musser's research equipment, experimental apparatus, and technical papers he used when he developed HarmonicDrive® in his home laboratory.

On the last day of their visit, Mrs. Yvonne Graham said, "The exhibition (Musser Heritage Room) was absolutely the best. My father usually didn't like to stand out and wanted to live life as a common person. As a result of visiting here, I felt that he was a special person after all. I hope he is very pleased with this opportunity." Mr. David Graham said, "I learned about the accomplishments of my grandfather. After listening to the explanations about the company and seeing how the company was operating, I learned that his accomplishments had made a contribution to people in Japan and around the world as well as the people working here. I look forward to your efforts to popularize HarmonicDrive® further. I will fully support you in such efforts."

After they returned home, Mr. David Graham sent a thank-you letter to HDSI. The following are some excerpts from the letter:

"The best part of the trip was the people we met and



Musser family members during a visit (at the Head Office and Hotaka Factory)

who became our friend... What a wonderful country that you live in and with such a rich history. You truly made us feel like royalty and especially my mother. I have never seen her have such a good time."

It was a memorable moment also because the market for HarmonicDrive® was then expected to grow.

**7-2 Construction of the New Factory of HPI**

After making a capital investment for fiscal 2014, HPI had a growing need for increasing the production of cross roller bearings. In March 2017, HDSI acquired factory premises for a new HPI factory and devised a construction plan. The main objectives were to improve the production efficiency by concentrating the production bases at three different sites in the New Matsumoto Industrial



Original text of the thank-you letter (in English)



Architectural renderings of the new factory of HPI



Introduction and installation of the machine tools



A bird's-eye view of the completed new factory of HPI

Park in one factory and to make the scale large enough to deal with future plans for the production increase.

On December 13, 2017, a ground-breaking ceremony was held before the construction of the new Matsumoto Factory of HPI was started. After the construction conducted by the contractor, the construction was completed in January 2019 as scheduled. It was a three-story steel frame building with a site area of 28,863m<sup>2</sup>, a building area of 14,435m<sup>2</sup>, and a total area of 30,295m<sup>2</sup>, which was comparable to the Hotaka Factory. A parking garage was also built. HDSI planned to rent the factory to HPI and commence its operation as the HPI factory starting March 2019. The plan was to introduce and install machine tools in phases while studying the trends in demand for production in the HDSI Group and to eventually raise the monthly production of cross roller bearings supplied to

HDSI from about 80,000 units to 150,000 units.

However, HDSI experienced a drop in performance during the construction. As a result, HDSI postponed the concentration of HPI, and started the operation of the factory with HDSI using one half of the first floor and HPI using the other half.

### 7-3 Construction of the Ariake Factory

#### Renovation of the Existing Factory and Construction of the New Factory

HDSI worked on developing a new production base to greatly increase the production capacity for HarmonicDrive®. HDSI selected the site (land and buildings) of the Ariake factory of Washington Shoe Co., Ltd. in Hotaka-riake, Azumino as the new factory site. After acquiring it



Architectural rendering of the new factory building constructed on the premises



Candidate site



Renovation of the factory building



Interior of the factory after renovation



Exterior views of the new Ariake Factory

on December 8, 2017, HDSI planned to renovate the existing two factory buildings to use them for urgent production increase activities.

On December 18, 2017, after a Shinto priest from Hotaka Shrine conducted a ceremony for the safe construction and prosperity of the Ariake Factory, the renovation of Building 1 (3,366m<sup>2</sup>) was started. The building began operations in March 2018. The renovation of Building 2 (2,730 m<sup>2</sup>) was conducted shortly after that, which was completed at the end of August of the same year.

On another front, HDSI planned to increase the total production capacity of the Ariake and Hotaka Factories to a monthly production of 200,000 units by March 2021 in anticipation of the expansion of major applications of HarmonicDrive®.

Against this background, HDSI devised a plan to construct a new factory building on the premises, and pursued the plan to construct it.

The new Ariake Factory building was a three-story steel frame building with a building area of 13,041 m<sup>2</sup> and a total area of 21,819 m<sup>2</sup>. The construction was started in September 2018, and completed in September 2019. After a completion ceremony and preview on September 10, the factory started operations.

### 7-4 Establishment of the Representative Office in Taiwan

In recent years, the Taiwan market has been gaining importance as a manufacturing and development center, especially for major EMS companies, electronic component manufacturers, and robot manufacturers.



Representative office in Taiwan

Although HDSI had a sales system in place centered around local distributors in Taiwan, it was far from sufficient due to a shortage of full-time personnel. HDSI had also been introducing products and doing promotional activities by taking monthly business trips to visit customers in Taiwan, but the sales remained flat. HDSI decided to establish an information collection and distribution hub in Taiwan to expand sales in the promising Taiwan market.

On May 10, 2016, HDSI established Harmonic Drive Systems Inc. Taiwan Representative Office near the Taipei station in Taipei as a representative office belonging to the Asia Group of the Sales Division. The Office started information collection and analysis on July 1. After adding a locally hired employee to create a workforce of two, the Office worked on deepening relationships with customers in Taiwan by developing new customers and improving relationships with the three distributors.

At the end of August 2016, HDSI

participated in the Taipei International Industrial Automation Exhibition for the first time as part of the sales expansion activities for promoting the value of Harmonic Drive® and HDSI's products to more customers and engineers. This was a machinery exhibition with a history of over 30 years with many foreign companies participating. Since then, HDSI has been participating every year to acquire new projects.



Exhibition at the Taipei International Industrial Automation Exhibition



Entrance of the venue



Venue of a lecture at the International Symposium

## 7-5 | The 6th Harmonic Drive® International Symposium

### First Symposium Held in Tokyo

On August 29 and 30, 2019, HDSI held the Harmonic Drive® International Symposium 2019. HDSI had been holding a symposium every five years, but decided to hold it a year ahead of schedule because it would coincide with the 50th anniversary if held in 2020 as scheduled. The venue was Plaza Heisei, Tokyo International Exchange Center, in Aomi, Koto-ku, Tokyo to provide easy access for the invited speakers and audience. There were a total of about 263 participants, about 200 of which were speakers and invited audience mainly consisting of customers, and 63 people who were in-house audience.

The overall theme of the symposium was “Total Motion Control” in a broad sense, not just limited to the products and technologies of HDSI. A total of 20 speeches were given; two keynote speeches, 15 speeches by invited speakers from Japan and overseas, and three speeches by in-house speakers. The keynote speeches were “Fun Research of Computer Vision and Robotics” by Takeo Kanade, U.A. and Helen Whitaker University Profes-

or, CMU, and “Human Robot Symbiosis - the Need for Smart Actuation” by Prof Guang-Zhong Yang, Director, The Hamlyn Centre, Imperial College of London.

### History of the International Symposium Series

HDSI held the first International Symposium in May 1991. It was planned as part of the celebration of the 20th anniversary and held at Azumino Hotaka View Hotel. The symposium had the following three objectives:

- (1) **To announce the research and development results and quality control technology of HDSI and publicize the technical activities inside and outside of the company.**
- (2) **To exchange information regarding HDSI's products between users and HDSI through technical presentations by users related to their applications for the development of new applications.**
- (3) **To provide opportunities for listening to speeches by researchers on motion control to advance knowledge in the company. To provide opportunities for users, researchers, and engineers of HDSI to interact with each other.**

## International Symposium Series

	Date	Venue	Presentation	Keynote Speech
The 1st HarmonicDrive® International Symposium 1991	May 23–24, 1991	Hotaka View Hotel	15	“Some Technical Renovations in History had Strong Influences on My Gear Research Works” by Takashi Nakada, Emeritus Professor, Tokyo Institute of Technology
The 2nd HarmonicDrive® International Symposium 1996	May 23–24, 1996	Hotel Buena Vista	16	“Robots and Human Beings” by Masahiro Mori, Emeritus Professor, Tokyo Institute of Technology
The 3rd HarmonicDrive® International Symposium 2001	November 20–21, 2001	Hotel Buena Vista	17	“Realistic Experience of Research and Development—in the case of Optical Communication” by Jun’ichi Nishizawa, President, Iwate University
The 4th HarmonicDrive® International Symposium 2006	October 5–6, 2006	Hotel Buena Vista	15	“Subaru Telescope—Exploring the Universe” by Keiichi Kodaira, President, The Graduate University for Advanced Studies, former Director-General of the National Astronomical Observatory of Japan
The 5th HarmonicDrive® International Symposium 2015	May 21–22, 2015	Hotel Buena Vista	16	“Designing the Next 100 Years” by Ken Kiyoyuki Okuyama, Industrial Designer, and “Future of Robotics (Service Robots Are Here)” by Steve Cousins, Savioke CEO
The 6th HarmonicDrive® International Symposium 2019	August 29–30, 2019	Tokyo International Exchange Center	20	Takeo Kanade, U.A. and Helen Whitaker University Professor, CMU, and Prof Guang-Zhong Yang, Director, The Hamlyn Centre, Imperial College of London

The overall theme of the 1st symposium was “Motion Control” in a broad sense, not just limited to Harmonic Drive®. To focus the spotlight from different angles, HDSI defined 3 sessions: (1) Research and development results and quality control technology of HDSI, (2) Applications of HarmonicDrive®, and (3) Recent control technologies. As a result of inviting users, engineers, and researchers in universities to speak, HDSI received many acceptances. Accordingly, a total of about 15 high-level research papers were published by speakers from Germany, the U.K., and the U.S., as well as researchers of Japanese research institutes and companies, group companies of HDSI, and engineers associated with HDSI. In addition, Takashi Nakada, Emeritus Professor of the Tokyo Institute of Technology at the time, gave a keynote

speech. HDSI also held a factory tour of the Hotaka Factory. The majority of the participants were customers, and the total exceeded 100.

Since then, HDSI had been holding a symposium every five years in principle. The table above shows the outlines of the symposiums. In 2011, the symposium was canceled in the planning stage due to the Great East Japan Earthquake.

## 7-6 | The Rampage of COVID-19

### Emergence of COVID-19 and Countermeasures Against It

Since the beginning of 2020, COVID-19 began its rampage around the world. It is an unprecedented infectious



disease that cannot be treated or controlled by modern medicine and science. HDSI decided on the policy of “prioritizing the safety and security of the employees.” On February 3, HDSI established the COVID-19 task force in the company for information sharing and prompt action because HDCH was located in China. As COVID-19 started spreading in Japan, HDSI took the following measures based on the basic policy of the Japanese government, focusing on the safety of the employees and their family members, customers, business partners and other parties concerned, prevention of outbreaks, and continued supply of products and services.

#### (1) Execution of operation

- Adopt staggered working hours for employees commuting by public transport in a metropolitan area
- Adopt teleworking and utilize teleconferencing
- Encourage employees not to come to work if they or their family member have a fever of 37.5°C or higher, or any symptoms of respiratory infections, such as coughs, nausea, and fatigue
- Check the body temperature of every employee upon entrance to a factory and/or office
- Promote hand washing and sanitizing upon entrance

to a factory and/or office

- Avoid non-essential business trips in Japan or overseas

- Encourage the employees of HDSI to wear a mask at internal and external business meetings

- Encourage visitors to HDSI to wear a mask

(2) Period of implementation

- Until the pandemic is determined to be over (based on the government guideline)

### COVID-19 Crisis and Financial Forecasts

The COVID-19 pandemic damaged the world economy, causing the COVID-19 crisis.

In the future, social conditions are expected to be difficult for a prolonged period of time, such as unprecedented economic turmoil, global employment insecurity, the China–United States trade war and fragmentation of the world economy, and uncertainty of social structures after the COVID-19 crisis (changes in common sense related to livelihood and economy).

On the other hand, an increase in demand for robots, one of the major applications of HDSI’s products, is expected due to the global promotion of labor-saving and



Core products "speed reducers and actuators"



Abacus drive

production innovation to avoid the Three Cs at production sites. However, the future trend in incoming orders is far from rosy, and there is a heightened sense of uncertainty about the future.

## 7-7 | Toward the Future

The HarmonicDrive® speed reducers, whose domestic production was started about 50 years ago, are now indispensable to motion control. It is a history of continuous growth through the creation of new applications along with the technical innovations in the world. During that period, HDSI has been opening up new markets while meeting customer demands by utilizing its development and technological capabilities.

And now, HDSI is facing another challenge requiring patience. Orders started to decline around April 2018, and have been at low levels since then.

The prime cause of the decline in orders is the sluggish growth of industrial robots in the Chinese market. The Chinese market once accounted for close to 60% of the sales of HDSI, so it has had a profound effect. However, the underlying reasons for the decline in orders from the

Chinese market seem to be more than trade issues such as temporary imbalance of supply and demand. It does not seem to be unconnected with the China–United States trade war and the national security problems in the United States.

Despite the complicated business environment, the business domain that HDSI has been developing over the past 50 years is very simple and easy to understand. The core products are "speed reducers and actuators." HDSI has not been involved in any other business. In the future, it is important to keep fulfilling its mission of providing quality products to the market at reasonable prices without losing sight of its business domain regardless of changes in the surrounding environment.

Seeking quality products is also essential as a measure against the competition that is growing by the day. As long as customers want a second source, HDSI needs to always be aware of the competitors and strengthen every aspect of QCDS\* more than ever.

To place the managerial focus on medium- to long-term improvement of the corporate value while resolving these challenges, HDSI started the Mid-Term Business Plan in April 2018. Today, HDSI focuses its efforts on the enhancement of competitiveness as a company with technologies

and skills for providing Total Motion Control.

In the Mid-Term Business Plan for 2020, HDSI defined the targeted corporate structure as "Continue to be without peer in the motion control industry through the provision of high-value products and services," and the targeted position as "A trusted actuator maker having original technology" and "A leading company in the precision speed reducer field."

Although HDSI is currently facing difficulties, its future is by no means bleak. In the markets of mechatronics products and precision speed reducers, which the HDSI Group deals with, an increase in demand for industrial robots and co-robots is expected in the developed countries to solve labor shortages and improve productivity, as well as in the emerging countries as investments for automation and labor-saving in the manufacturing industry. As such, medium- to long-term high growth prospects are solid.

Furthermore, the industrial robot market is expected to grow at a CAGR of approximately 15% after 2018. Especially, high hopes are placed on co-robots that can cooperate with humans without a safety fence. While the growth of industrial robots took about 50 years, co-robots

are expected to grow rapidly, the annual production of which is expected to reach that of industrial robots in a short period of 10 years by 2025.

With a positive outlook for the future, HDSI aims at achieving the objectives in the Mid-Term Business Plan within the target period to lay the foundations for growth towards 2030 and 2050, namely, market introduction of the Abacus drive (pure rolling cycloid), testing and assessment of new materials and new principles, promotion of positive access to peripheral technologies, and promotion of interaction with other research institutes and industries.

HDSI is currently facing a headwind, but is not and has not been pessimistic. Taking this as an opportunity for change, HDSI is focusing on building a more robust management culture. The company is steadily setting the stage for springing into action in the upcoming period of expansion.

## 7-8 | Celebration of the 50th Anniversary

It is generally believed that the lifespan of a company is 30 years and only 0.02% of companies can survive for 30

\* Quality, Cost, Delivery, and Service as the indicators for product evaluation



Chairman Ito giving a lecture



President Nagai giving a speech

years or longer. Thanks to the HarmonicDrive® products, HDSI celebrated the 50th anniversary.

HDSI decided on its slogan and symbol logo mark on May 7, 2019. The purpose was to get across its achievements over 50 years, share its vision, and improve motivation toward the next 50 years with a sense of togetherness and the joy of working at the company. The logo and slogan “Pioneering the Future of Total Motion Control” were selected from the four sets of logos and slogans preselected at the 50th anniversary celebration project meeting based on an in-house questionnaire. The symbol logo mark and slogan were to be used on business cards, printed materials, websites, and email signature blocks.

In August 2019, HDSI held the “Harmonic Drive International Symposium 2019” celebrating the anniversary. HDSI is planning to hold the “Harmonic Lecture” in October 2021 and the “Harmonic Concert” in March 2022 for celebrating the anniversary.

On November 6, 2020, HDSI held an anniversary ceremony for the employees. The ceremony was intended to convey the company’s thankfulness and vision to the employees, business partners, the Cooperating Association, and shareholders. However, the situation did not allow HDSI to hold a public ceremony due to the prolonged COVID-19 pandemic.

The cafeteria of the Ariake Factory was used as the main venue of the anniversary ceremony, where attendance was limited to Chairman Mitsumasa Ito, President Akira Nagai, Directors, Executive Officers, and Auditors living in Nagano Prefecture, and employees to be awarded for long service. Other employees were divided into different venues with preventive measures against COVID-19 in place, where they watch the live streaming.

The ceremony started with a speech by President Akira Nagai, followed by a lecture by Chairman Mitsumasa Ito, awarding of long service awards, and a group photo shoot.

On the day, red and white buns celebrating the 50th anniversary were distributed to the employees. The employees were offered three types of commemorative gifts to choose from. Prepaid cards and Parker ballpoint pens were distributed to the general public.

The attendees shared gratitude for the many individuals who had supported the company for the past 50 years, including Musser who invented the extraordinary product HarmonicDrive®, early pioneers who worked hard through the early days of its introduction to Japan, and forerunners who created new markets by earnestly dealing with customers and their needs.



A scene from the venue of the anniversary ceremony



Symbol logo mark and slogan for the 50th anniversary

*Pioneering the Future of  
Total Motion Control*



Commemorative gifts distributed at the anniversary ceremony



Five red and white buns distributed at the anniversary ceremony

## Harmonic Concert Series

No.	Date	Artists
1st	November 22, 1980	Yoko Nakayama recital
2nd	November 25, 1981	Yuko Fujimura piano recital
3rd	March 13, 1983	Koji Toyada (violin) and Motoko Toyoda (piano) recital
4th	May 13, 1984	Mitsuko Shirai (soprano) and Hartmut Höll (piano) duo recital
5th	June 23, 1985	Hiroyuki Iwaki percussion instrument recital commemorating the 15th anniversary Hiroyuki Iwaki (percussion), Toshi Ichiyonagi (piano), Kaori Kimura (piano), Kazunori Momose (percussion), Kazunori Meguro (percussion), and Yashio Sudo (percussion)
6th	June 14, 1986	Mitsuko Shirai (mezzo-soprano) and Hartmut Höll (piano) duo recital
7th	June 5, 1987	Yuko Fujimura piano recital
8th	June 18, 1988	Tadao Yoshie (baritone) and Michael Gees (piano) recital
9th	July 1, 1989	Toru Yasunaga (violin) and Ayumi Ichino (piano) recital
10th	April 21, 1990	Harmonic Concert commemorating 20th anniversary Mitsuko Shirai (mezzo-soprano), Hartmut Höll (piano), Tabea Zimmermann (viola), and Eduard Brunner (clarinet)
11th	October 5, 1991	Tadao Yoshie (baritone) and Misao Minemura (piano) recital
12th	June 4, 1994	Yuko Fujimura piano recital
13th	April 15, 1995	Harmonic Concert commemorating 25th anniversary Mitsuko Shirai (mezzo-soprano) and Hartmut Höll (piano) duo recital
14th	April 27, 1996	Soichiro Ohno (horn), Tsugio Tokunaga (violin), and Kei Itoh (piano) recital
15th	May 24, 1997	Teruji Karashima (piano), Hirofumi Kanno (cello), and Keiko Urushihara (violin) recital
16th	May 30, 1998	Tsugio Tokunaga (violin) and Shigeo Neriki (piano) recital
17th	May 22, 1999	Yuko Fujimura piano recital
18th	May 20, 2000	Harmonic Concert commemorating 30th anniversary Mitsuko Shirai (mezzo-soprano), Christoph Prégardien (tenor), and Hartmut Höll (piano)
19th	May 19, 2001	Teruji Karashima (piano), Soichiro Ohno (horn), Tomoyuki Hirota (oboe), Tomomi Takahashi (clarinet), and Kohji Okazaki (bassoon) recital
20th	May 25, 2002	Tsugio Tokunaga (violin), Noboru Kamimura (cello), and Shigeo Neriki (piano) recital
21st	May 24, 2003	Mitsuko Shirai (mezzo-soprano), Christoph Prégardien (tenor), and Hartmut Höll (piano) (sponsored jointly with the Hugo Wolf Society of Stuttgart, Germany commemorating the 100th anniversary of the death of Hugo Wolf)
22nd	May 29, 2004	Teruji Karashima (piano), Hiroaki Kanda (flute), Tomoyuki Hirota (oboe), Shuhei Isobe (clarinet), Kohji Okazaki (bassoon), and Soichiro Ohno (horn) recital
23rd	May 28, 2005	Harmonic Concert commemorating 35th anniversary - Yuko Fujimura piano recital
24th	May 27, 2006	Tsugio Tokunaga (violin) and Hiroko Komoriya (piano) recital
25th	May 26, 2007	Soichiro Ohno (horn), Reiko Honjo (piano), and Daishin Kashimoto (violin) recital
26th	May 24, 2008	Tadao Yoshie (baritone) and Jörg Demus (piano) recital
27th	June 6, 2009	Tsugio Tokunaga (violin) and Eri Hayashi (piano) recital
28th	October 2, 2010	Harmonic Concert commemorating 40th anniversary Mitsuko Shirai (mezzo-soprano) and Hartmut Höll (piano) recital
29th	September 29, 2012	Momoo Kishibe (violin) and Hiroyuki Abe (piano) recital
30th	October 5, 2013	Tsugio Tokunaga (violin) and Eri Hayashi (piano) recital
31st	May 24, 2014	Japan Concert by the Chamber Ensemble of the Frankfurt Radio Symphony Orchestra Susanne Stoodt (1st. violin), Gerhard Miesen (2nd. violin), Gerd Gröttschel (viola), Peter Wolf (cello), Soichiro Ohno (1st. horn), and Thomas Sonnen (2nd. horn)
32nd	July 4, 2015	10th anniversary of the municipal system of Azumino City Yuko Fujimura piano recital
33rd	May 28, 2016	Tsugio Tokunaga (violin) and Eri Hayashi (piano) recital
34th	May 27, 2017	Teruji Karashima (piano), Momoo Kishibe (violin) and Fumiaki Kono (cello) recital
35th	June 2, 2018	Soichiro Ohno (horn) and Yasuo Watanabe (piano) recital
36th	December 21, 2019	Fumiaki Miura (violin) and Maika Miura (piano) recital
37th	March 2022 (scheduled)	Tsugio Tokunaga (violin), Noboru Kamimura (cello), and Shigeo Neriki (piano) recital

## Harmonic Lecture Series

No.	Date	Speaker	Title at the time	Title
1st	October 5, 1996	Teru Miyamoto	Writer	"What You Get from Travel"
2nd	October 4, 1997	Jun'ichi Nishizawa	Former President of Tohoku University	"The Meaning of Creative Technology"
3rd	October 17, 1998	Fumihiko Maki	Former professor of the University of Tokyo, present principal of Maki and Associates	"Presenting Space and Landscaping"
4th	October 2, 1999	Keiichi Kodaira	Director-General of the National Astronomical Observatory of Japan	"Start of Observations by the Subaru Astronomical Telescope"
5th	October 6, 2000	Teru Miyamoto	Writer	"A 6,700 km Journey Along the Silk Road"
6th	November 6, 2001	Hajime Karatsu	Professor, Tokai University	"Innovative Manufacturing-The Only Key to Japan's Future"
7th	October 4, 2002	Hiroyuki Agawa	Writer	"Humor and the Japanese"
8th	November 21, 2003	Kazuhide Uekusa	Professor, the Okuma School of Public Management, Waseda University	"The Path Toward Revival of the Japanese Economy"
9th	October 15, 2004	Eiin Yasuda	Chief Priest of Yakushi-ji Temple	"In Quest for Ideal Land"
10th	November 18, 2005	Yoshiko Sakurai	Journalist	"Education Opens the Path to the Future"
11th	October 12, 2007	Shumon Miura	Writer	"Japan in Asia"
12th	October 24, 2008	Takeshi Watanabe	Honorary Professor, Ph.D. in Physics, Tohoku University	"The Joy of Learning and Courage to Teach Others"
13th	November 5, 2010	Noriko Hama	Professor, Doshisha University Graduate School of Business	"What Will Happen Next to Japan and the World in the Global Jungle?"
14th	April 5, 2013	Gerald L. Curtis	Professor, Department of Political Science, Columbia University	"Upheaval of Japan-U.S Relation in Asia"
15th	November 14, 2014	C.W. Nicol	Author, naturalist	"Harmony of Humans and Nature"
16th	October 30, 2015	Shunji Yanai	Former Japanese ambassador to the U.S.	"East Asia's Transformation and Japan's Security"
17th	October 18, 2016	Junichiro Koizumi	Former Prime minister	"Path Japan Should Take"
18th	October 26, 2017	Keiko Kishi	Actress, writer	"Les Formes de L'Amour"
19th	October 25, 2018	Taichi Sakaiya	Writer, economic critic	"From Showa and Heisei to a New Era: Building a New Japan"
20th	October 18, 2019	Sadayuki Sakakibara	Honorary chairman of the Japan Business Federation	"The Path Toward Revival of the Japanese Economy"
21st	October 2021 (scheduled)	Mamoru Mohri	Astronaut	"Post-COVID Society as Seen from Space"

## Corporate Information

[Corporate Name]	Harmonic Drive Systems Inc.
[Head Office]	6-25-3 Minami-Oi, Shinagawa-ku, Tokyo 140-0013, Japan
[Founded]	October 27, 1970
[Representative]	Mitsumasa Ito, Chairperson, Representative Director Akira Nagai, President, Representative Director
[Capital]	¥7,100 million (as of March 31, 2021)
[Our Business Domain]	Production and sales of mechatronics products and the following speed reducer brands for incorporation in industrial robots, semiconductor manufacturing equipment, and other systems. - Strain Wave Gearing "HarmonicDrive®" - High-precision Planetary-gear Speed Reducer "AccuDrive®" and "HarmonicPlanetary®"
[Employees]	Consolidated: 1,104 Non-consolidated: 406 (as of March 31, 2021)
[Net Sales]	Consolidated: ¥37,034 million, Non-consolidated: ¥ 24,264 million (as of March 31, 2021)
[Company Sites]	<ul style="list-style-type: none"> <li>- <b>Head Office</b> Ichigo Omori Bldg., 4F 6-25-3 Minami-Oi, Shinagawa-ku, Tokyo 140-0013 Japan</li> <li>- <b>Hotaka Factory</b> 1856-1 Hotakamaki, Azumino-shi, Nagano 399-8305 Japan</li> <li>- <b>Ariake Factory</b> 5103-1 Hotakaariake, Azumino-shi, Nagano 399-8301 Japan</li> <li>- <b>Tokyo Office</b> Ichigo Omori Bldg., 4F 6-25-3 Minami-Oi, Shinagawa-ku, Tokyo 140-0013 Japan</li> <li>- <b>Tokyo Office Kitakanto Team</b> Ichigo Omori Bldg., 4F 6-25-3 Minami-Oi, Shinagawa-ku, Tokyo 140-0013 Japan</li> <li>- <b>Kohshin Office</b> 5103-1 Hotakaariake, Azumino-shi, Nagano 399-8301, Japan (Ariake Factory)</li> <li>- <b>Chubu Office</b> TM21 Bldg., 2F 21 Terugaoka, Meitoku, Nagoya-shi, Aichi 465-0042, Japan</li> <li>- <b>Kansai Office</b> Shin-Osaka Ueno Toyo Bldg., 3F 7-4-17 Nishi-Nakajima, Yodogawa-ku, Osaka-shi, Osaka 532-0011, Japan</li> <li>- <b>Kyushu Office</b> NMF Hakata-Ekimae Bldg., 7F 1-15-20 Hakata Ekimae, Hakata-ku, Fukuoka-shi, Fukuoka 812-0011, Japan</li> <li>- <b>Overseas Sales Division</b> 5103-1 Hotakaariake, Azumino-shi, Nagano 399-8301 Japan (Ariake Factory)</li> <li>- <b>Harmonic Drive Systems Inc. Taiwan Representative Office</b> RmG219, 11F., No.209, Sec.1, Civic Blvd., Datong Dist., Taipei City 10351, Taiwan (R.O.C.)</li> </ul>

### [Group Companies]

#### Domestic

##### HD Logistics, Inc.

- Head Office: 1856-1 Hotakamaki, Azumino-shi, Nagano 399-8305, Japan
- Founded: April 1999
- President: Toyoyasu Maruyama
- Business Domain: Logistics
- Owned by Harmonic Drive Systems Inc.: 100%

##### Harmonic Precision Inc.

- Head Office: 7107-53 Kosakamichi, Kanbayashi, Matsu-moto-shi, Nagano 390-1243, Japan
- Founded: July 1999
- President: Osamu Asakura
- Business Domain: Production of cross roller bearings
- Owned by Harmonic Drive Systems Inc.: 100%

##### Harmonic AD, Inc.

- Head Office: 4034 Toyoshina, Azumino-shi, Nagano 399-8205, Japan
- Founded: April 2003
- President: Isao Mimura
- Business Domain: Production of AccuDrive® and Harmonic Planetary® high-precision planetary reducers
- Owned by Harmonic Drive Systems Inc.: 100%

##### GK HD Management

- Head Office: Ichigo Omori Bldg., 4F 6-25-3 Minami-Oi, Shinagawa-ku, Tokyo 140-0013, Japan
- Founded: December 2016
- Representative: Harmonic Drive Systems Inc., Representative Member Akira Nagai, Shokumu Shikkosha
- Business Domain: Holding company for the purpose of investment in Harmonic Drive SE
- Owned by Harmonic Drive Systems Inc.: 100%

##### Winbel Corporation

- Head Office: 8172-60 Akaho, Komagane-shi, Nagano 399-4117, Japan
- Founded: June 1994
- President: Takahisa Tezuka
- Business Domain: Development, mass production support, manufacturing, and sales of various motors
- Owned by Harmonic Drive Systems Inc.: 100%

##### Ome Iron Casting Co., Ltd.

- Head Office: 3-11-1 Nagaoka, Mizuho-machi, Nishitamagun, Tokyo 190-1232, Japan
- Founded: October 1945
- President: Takuro Miyoshi
- Business Domain: Development, production, and sales of high-strength cast-iron products
- Owned by Harmonic Drive Systems Inc.: 49.2%

#### Overseas

##### HD Systems, Inc.

- Head Office: 247 Lynnfield Street, Peabody, Massachusetts 01960, U.S.A.
- Founded: February 1987
- President: Akira Nagai
- Business Domain: American holding company
- Owned by Harmonic Drive Systems Inc.: 100%

##### Harmonic Drive L.L.C.

- Head Office: 42 Dunham Ridge, Beverly, Massachusetts 01915 U.S.A.
- Founded: December 2005
- President and CEO: Douglas Olson
- Business Domain: Development, production, and sales for mechatronic products and reduction gears
- Owned by HD Systems, Inc.: 100%

##### Harmonic Drive SE

- Head Office: Hoenbergstrasse 14 D-65555 Limburg a.d. Lahn, Germany
- Founded: November 1970
- President: Norimitsu Ito
- Business Domain: Development, production, and sales for mechatronic products and reduction gears
- Owned by Harmonic Drive Systems Inc.: 100%

##### Harmonic Drive Systems (Shanghai) Co., Ltd.

- Head Office: Rm206, 1#, No.641, Tianshan Rd, Changning District, Shanghai, 200336, China
- Founded: January 2011
- Chairperson: Michiya Yashiro
- Business Domain: Sales and technical services of mechatronics products and reduction gears
- Owned by Harmonic Drive Systems Inc.: 100%

##### SAMICK ADM CO., LTD.

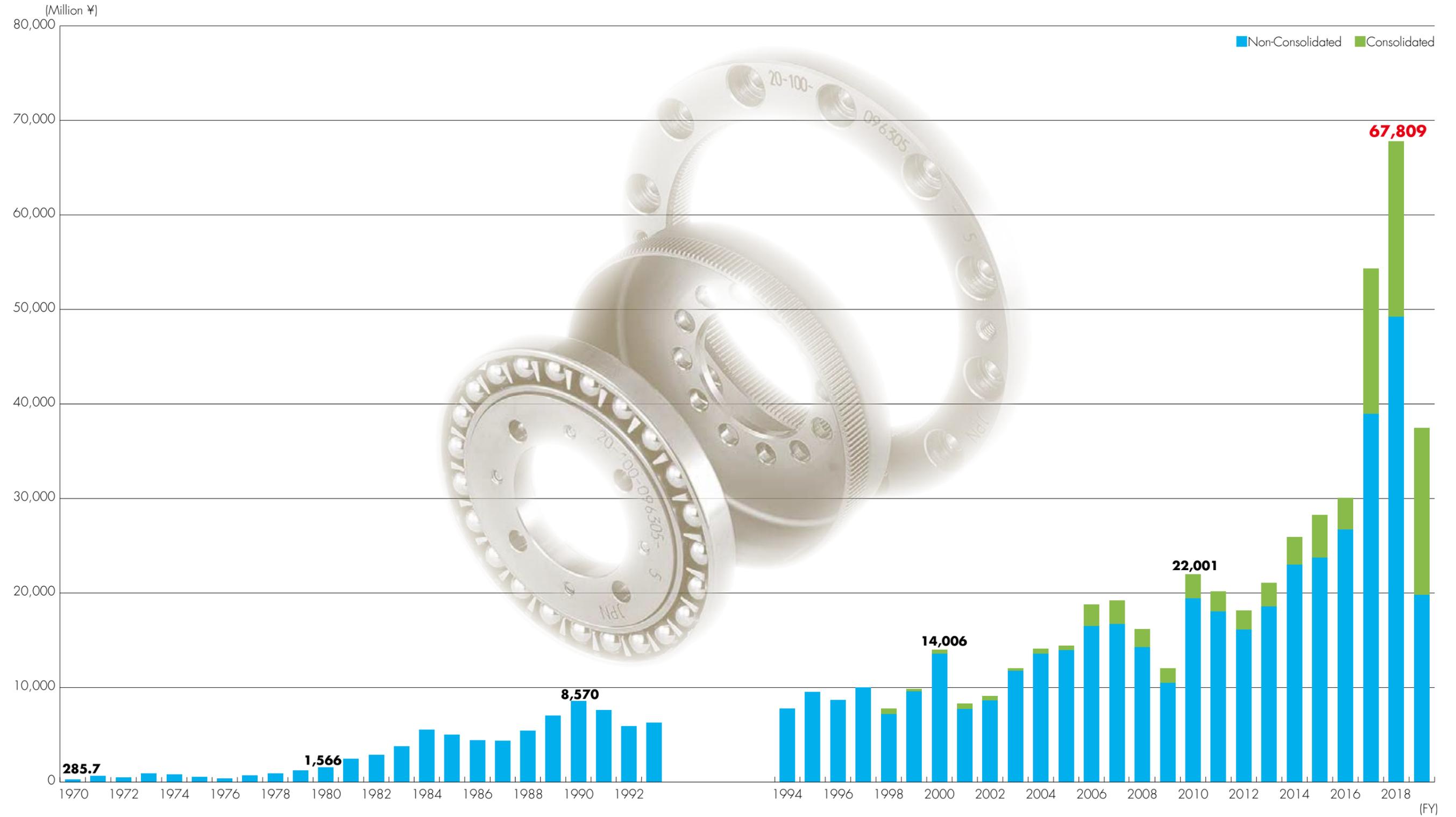
- Head Office: Dalseong 2chadong 2-ro 66, Guji-Myeon, Dalseong-gun, Daegu, Korea
- Founded: February 2013
- President: Hyun-Woo Jin
- Business Domain: Manufacturing precision planetary gears
- Owned by Harmonic Drive Systems Inc.: 51%

##### Harmonic Drive Systems Inc. Taiwan Representative Office

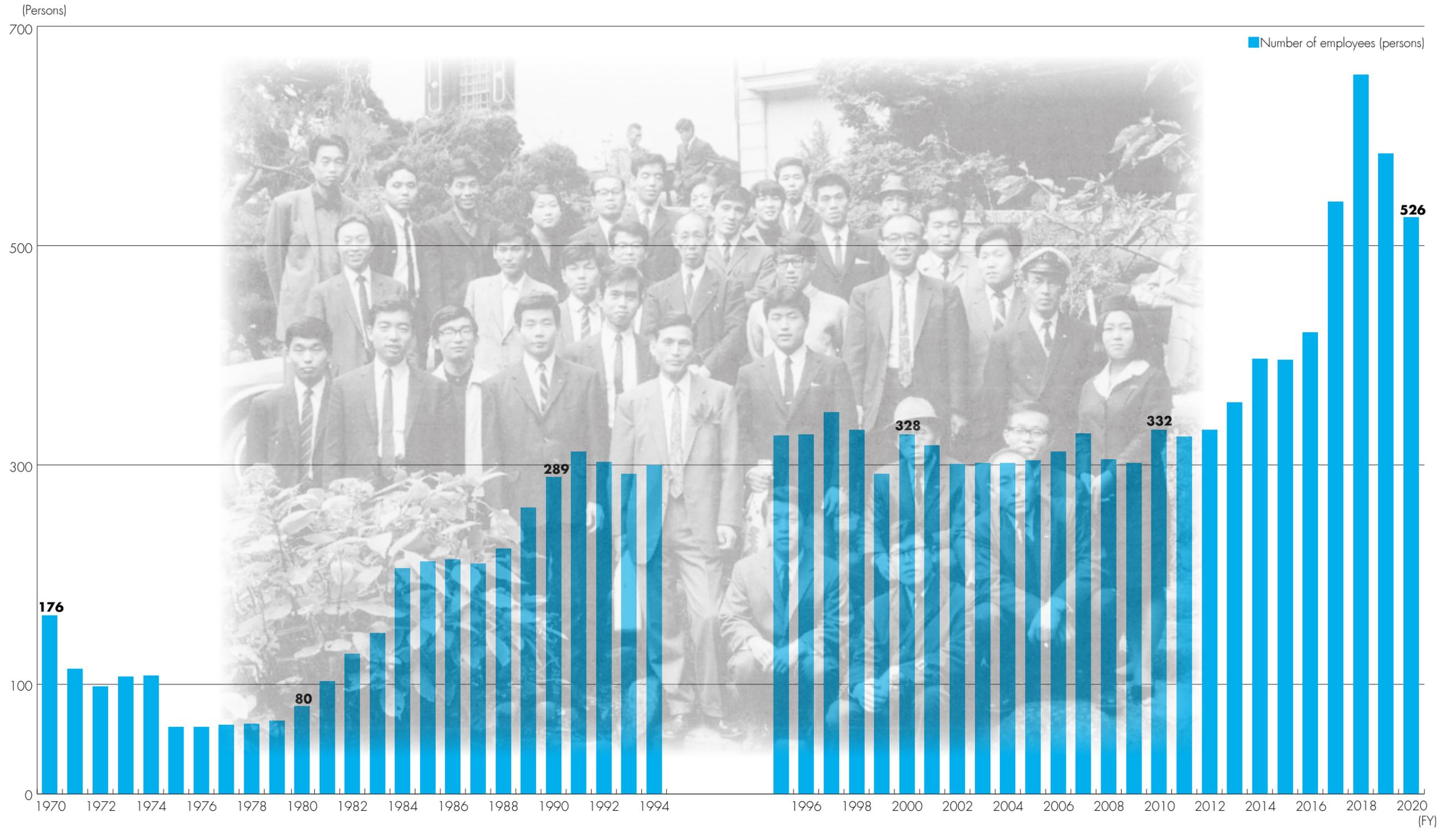
- Head Office: RmG219, 11F., No.209, Sec.1, Civic Blvd., Datong Dist., Taipei City 10351, Taiwan (R.O.C.)
- Business Domain: Sales and technical services of mechatronics products and reduction gears

\* Representative office of Harmonic Drive Systems, Inc.

# Sales Trends



# Number of Employees



## Current Directors & Executives



### (1) Mitsumasa Ito

Chairperson, Representative Director

### (2) Akira Nagai

President, Representative Director / Chief Executive Officer

### (3) Akira Maruyama

Director / Executive Officer (General Manager of Corporate Planning)



**Tetsuo Ikuta**  
Executive Officer  
President and CEO of Harmonic Drive Systems (Shanghai) Co., Ltd.



**Haruhiko Yoshida**  
Independent Outside Director



**Shinji Sakai**  
Independent Outside Director



**Masanobu Nakamura**  
Independent Outside Director



**Yoshio Fukuda**  
Independent Outside Director



**Hideo Yasue**  
Standing Corporate Auditor



**Yoshitsugu Yokogoshi**  
Standing Corporate Auditor, Outside Corporate Auditor, and Independent Auditor



**Shigeto Ohashi**  
Outside Corporate Auditor



**Eisaku Imazato**  
Outside Corporate Auditor and Independent Auditor

### (4) Yoshinori Ito

Director / Executive Officer (Quality Control Manager)

### (5) Kazutoshi Kamijoh

Director / Executive Officer (General Manager of Finance, Accounting, and Tax)

### (6) Minoru Asano

Senior Executive Officer (In charge of Production, Production Planning, Production Technology, and Supply Chain) (General Manager of First Production Division, Supply Chain)

### (7) Michiya Yashiro

Executive Officer (In charge of Marketing and Sales) (General Manager of Sales Strategy and Overseas Sales)

### (8) Hidefumi Iguchi

Executive Officer (General Manager of Administration and Human Resources)

### (9) Yoshihide Kiyosawa

Executive Fellow Officer (Chief Technical Officer) (Chief of Harmonic Drive Laboratory)

### (10) Yoshihiro Tanioka

Executive Officer (General Manager of Development and Engineering)

### (11) Tetsuaki Maruyama

Executive Officer (General Manager of Second Production Division)

### (12) Hiroshi Ozawa

Executive Officer (In charge of Public Relations)

## Chronology

Year	Mo.	Events at HDS
1964	6	Hasegawa Gear Works and United Shoe Machinery Corporation signed a technology partnership agreement for HarmonicDrive®.
	11	The Japanese government approved the technology partnership agreement for HarmonicDrive®.
	11	Formed the Harmonic Drive Technical Support Committee.
1965	12	Established the Harmonic Drive Division.
	1	Vice president Hasegawa, Manager of the Development Department Kameda, Chief of the Engineering Section Ishikawa, and Chief of Production Engineering Arita visited USM to acquire technologies related to HarmonicDrive® (and returned to Japan in February).
	4	Exhibited imported standard products at the 6th Tokyo International Trade Fair.
1966	7	Completed the first standard type HarmonicDrive® speed reducer.
	8	Delivered the first standard type HarmonicDrive® speed reducer to Hitachi, Ltd.
	8	Received an order for 84 units, getting off to a good start.
	10	Signed a distributor agreement with Mitsui & Co., Ltd.
	4	Exhibited panels at the Osaka International Trade Fair.
	7	Delivered large sizes of HarmonicDrive® to Hitachi Zosen Corporation.
1967	7	Held a 10-day technical workshop for distributors.
	1	Created an assembly area by partitioning the heat treatment area to establish a production system up to fabrication, albeit small in size.
	2	W. N. Bley, vice general manager of British United Shoe Machinery in Europe, visited the company, providing a foothold in the European market.
1968	4	Exhibited a total of 30 units of varying sizes of HarmonicDrive® at the Tokyo International Trade Fair to promote its characteristics on a full scale.
	9	Mr. Bliss, division director of USM, visited the company.
	4	Kiichiro Hasegawa was awarded the Blue Ribbon Medal.
1969	6	Abandoned the director/section chiefs system and introduced a system tentatively called the tentative desk system.
	12	Thomas D. Welch, vice president of USM, became a new officer.
	6	Started the new desk system as a functional organization structure.
1970	9	Held a workshop with 50 participants for front-line salespersons of the HarmonicDrive® distributors.
	2	Concluded the negotiation on establishing a 50/50 joint venture with USM.
	7	Purchased factory premises in Toyoshina, Nagano Prefecture.
	8	Ten interns who were selected from the employees of Toyoshina Carton and passed the job interview took part in OJT training on assembly and machinery.
	8	Formed a preparatory committee to relocate to the acquired factory in Toyoshina (tentatively called Hasegawa Gear Works Matsumoto Factory).
	9	Made an arrangement with the labor union regarding the transfer of the Harmonic Drive Division to the joint venture and its relocation to the Matsumoto Factory (currently the Toyoshina Factory).

Year	Mo.	Events at HDS
1970	10	Held the inaugural meeting of Harmonic Drive Systems, Inc. (October 26). President, Representative Director: Kiichiro Hasegawa, Director: Ryuichi Fujii, Hiroshi Kameda, and Atsuo Tokoro, Auditor: Toshio Toi
	10	Harmonic Drive Systems Inc. was established (October 27).
	11	Received assets including machines and tools worth 350 million yen transferred from Hasegawa Gear Works.
	11	Established Harmonic Drive System GmbH (hereafter called HDSG, currently HDSE) in Germany.
	11	Started manufacturing HarmonicDrive® at the Matsumoto Factory (currently the Toyoshina Factory).
	11	Signed an agency agreement for the products with Mitsui & Co., Ltd.
	12	Harmonic Drive Systems Inc. was formally approved as a joint venture of Hasegawa Gear Works and USM (December 11).
1971	2	Appointed new officers. President, Representative Director: Kiichiro Hasegawa, Vice President: Robert A. Seyce, Director: Paul W. Berton, Joseph Ranger, Ryuichi Fujii, Hiroshi Kameda, and Atsuo Tokoro, and Auditor: Tetsuo Sato and Toshio Toi
	2	Relocated the Head Office from Minami-Rokugo, Ota-ku, Tokyo to Roppongi, Minato-ku, Tokyo.
	5	Appointed Shoji Hata and Noboru Hiraoka as Directors.
	8	Demoted all managers for inadequacies in the management systems.
	10	Integrated purchasing operations at the Tokyo Head Office into the Matsumoto Factory (currently the Toyoshina Factory) for streamlining.
1972	4	Decided on a 5-year plan for transitioning to a five-day workweek (with a total of 83 holidays initially, including 9 designated holidays and 9 Saturdays in addition to Sundays and public holidays).
	5	Appointed Shoko Odate (who returned to Japan) as a Director.
1973	1	Set alternate Saturdays as holidays.
	2	Extended the retirement age to 60 with conditions.
	5	Assembled the assembly streamlining project team and started to consider how to streamline assembly operations.
	5	Appointed Atsuo Tokoro as Executive Director.
1974	12	Improved the overtime compensation policy.
	1	Set 111 holidays a year.
	5	Appointed new officers. Vice President: Willard B. Spring, Director: Wilber W. Lauer, Auditor: Keijiro Murata, replacement Vice President: Robert A. Seyce, Director: Paul W. Berton, and Auditor: Tetsuo Sato
1975	6	Concluded an overtime work agreement (up to 15 hours per week and 45 hours per month).
	1	Transitioned to a five-day workweek. Four days each as year-end and new-year holidays and summer holidays, and one day each for the May Day holiday and the anniversary of the founding (251 working days per year, 1,945.25 working hours per year).
	1	Assembled the Bullbags special sales unit as a factory streamlining measure, marketing it mainly in the Hokushinetsu area.
	7	Received the employment adjustment subsidies.
	7	Received the "Nagano Labor Standards Inspection Office Director Award for Progress" in the National Safety Week.
	10	Set up a short-term sales structure for Bullbag. Dispatched 2 employees to Hasec Engineering for 4 months.
1976	2	Closed the Nagoya Office and put the operation under the jurisdiction of the Tokyo Office.

Year	Mo.	Events at HDS	
1976	5	Hasegawa Gear Works applied for the Corporate Reorganization Law.	
	8	Reduced the capital from 200 million yen to 100 million yen.	
	9	Developed actuators for lightweight shutters (started with a monthly production of 200 units).	
	9	Became a wholly owned subsidiary of USM (Capital: 100 million yen).	
	9	Relocated the Head Office from Minami-Rokugo, Ota-ku, Tokyo to Daihyaku Seimei Building in Nishikamata, Ota-ku, Tokyo.	
	9	Appointed new officers. President, Representative Director: Joseph Ranger, Vice President: Atsuo Tokoro, Executive Director: Shoji Hata, Director: Frank T. Pierce and Steven J. Rifai, and Auditor: Tetsuo Sato	
	1977	4	Adopted the manager system.
		7	Introduced the retirement pension plan (qualified retirement pension).
		11	Started the manufacturing and sales of mechatronics products.
1978	1	Set an annual goal of building a recession-proof structure by thorough cost reduction.	
	1	Introduced the product manager system.	
		Sold "RESPONSYN" manufactured by USM as part of the business development of the AP Group.	
		Transitioned from the distributor sales system to the direct and parallel sales system and started direct sales efforts as part of the customer-centric policy.	
1979	6	Appointed Dr. Toshio Aida, professor emeritus of Kyoto University, as an Adviser.	
	8	Started anew as Harmonic Drive Systems Inc. (separating from Emhart).	
	8	Appointed new officers. President, Representative Director: Atsuo Tokoro, Vice President: Toshiro Kawamoto, Executive Director: Shoji Hata, Director: Akira Arakawa, Mitsumasa Ito, and Auditor: Satoshi Wanibuchi	
	11	Received the "Nagano Labor Standards Inspection Office Director Award for Best Effort" in the National Occupational Health Week.	
1980	1	Started the "compulsory improvement movement activities."	
	4	Materialized "quality-oriented management" as the second 3-year Mid-Term Business Plan.	
	6	Received a gold award for a product exhibited at Trade Fairs Brno in Czechoslovakia.	
	6	Declared the introduction and promotion of Total Quality Control (TQC).	
	6	Launched Operation Z for TQC.	
	11	Held the 1st Harmonic Concert - a recital by Yoko Nakayama.	
	11	Introduced computers (Toshiba T-15 DK: 10MB MM: 128KB) to the factory.	
1981		Set up a QC circle and held QC meetings.	
	10	Completed the 1st phase extension work of the Matsumoto Factory (currently the Toyoshina Factory).	
	11	Held the 2nd Harmonic Concert - a piano recital by Yuko Fujimura.	
1982		Started the planning for the use of electronic data processing for the productivity management system.	
	9	Started to operate the sales information processing system (at the factory).	
	11	Completed the 2nd phase construction work of the Matsumoto Factory (currently the Toyoshina Factory).	
		Assembled the robotic team for high-precision HDs.	
		Started the MAC project for the productivity management system.	

Year	Mo.	Events at HDS
1983	3	Held the 3rd Harmonic Concert - a recital by Koji Toyoda (violin) and Motoko Toyoda (piano).
	5	Held a party to celebrate the completion of the factory.
	5	Created the first company slogan "Beat the competition, challenge obstacles, and overcome them" according to the president's policy.
	7	Opened the Kyushu Office (Hakata-ku, Fukuoka-shi).
	10	Relocated the Head Office from Nishikamata, Ota-ku, Tokyo to Oimachi, Shinagawa-ku, Tokyo. Established the FA Equipment Division.
1984	3	Changed compulsory company trips to personal/group trips (by granting subsidies for trips).
	5	Held the 4th Harmonic Concert - a recital by Mitsuko Shirai (soprano) and Hartmut Höll (piano).
	5	Held a HD national distributor meeting to create a national organization for the sales expansion meeting system.
	6	Started the HPS project. Goal: Reduce production lead time by 50%, and improve productivity by 30%.
	7	Launched a TV commercial for recruitment advertising (a 30-second ad during the high school baseball tournament from July 15 to 25).
	7	Installed air conditioners at the factory.
	9	Relocated the Osaka Office from the Fukushima Building in Fukushima-ku, Osaka to the First Building in Fukushima-ku, Osaka.
	11	Received an order for special FR prototypes (3 types) from Volkswagen. Started the 1st phase CAD system program.
1985	4	Completed construction of the office building of the Matsumoto Factory (currently the Toyoshina Factory) (3rd phase).
	5	Held a party to celebrate completion of alteration and extension of the Matsumoto Factory (currently the Toyoshina Factory).
	6	Opened the Tokyo Office (Oi, Shinagawa-ku).
	6	Held the 5th Harmonic Concert celebrating the 15th anniversary - a percussion recital by Hiroyuki Iwaki.
	7	Opened the Kofu Office (Marunouchi, Kofu).
	11	Held the 15th anniversary ceremony (at Matsumoto Tokyu Inn 2). Started the production of the unit type for Volkswagen.
	1986	1
2		Assembled the ZD team to aim for Zero Defects.
3		Received a major order from Volkswagen and started production.
4		Opened the Kanazawa Office (Honmachi, Kanazawa).
4		Acquired factory premises in Maki, Hotaka-machi.
6		Held an international technical conference (at the Matsumoto Factory, currently the Toyoshina Factory).
7		Introduced the three division system.
11		Relocated the Kofu Office to the premises of the Matsumoto Factory (currently the Toyoshina Factory) and opened the Matsumoto Office.
11		Filed a patent for the IH tooth profile.

Year	Mo.	Events at HDS	
1987	2	Established HD Systems, Inc. (hereafter called HDSys) in the United States.	
	4	Signed a distributorship agreement with Mitsui & Co., Ltd. for sales of HDSI's products in Korea. Launched the HD technology export project (F project).	
	8	Held the 3rd international technical conference (at the Matsumoto Factory, currently the Toyoshina Factory), visited by R. Müller of Volkswagen.	
1988	9	Tetsuo Ikuta (Mitsui & Co., Ltd.) was dispatched to HDSys.	
	12	Decided to split the Tokyo Office into three offices: Tokyo, Omiya, and Yokohama. Proposed "Total Motion Control."	
	1	Opened the Omiya Office (Miyacho, Omiya).	
	1	Opened the Yokohama Office (Naka-ku, Yokohama).	
1989	2	Established new Harmonic Drive Systems Inc. as a wholly owned subsidiary of former Harmonic Drive Systems Inc.	
	4	Sasahara, Ishikawa, and Kiyosawa gave a presentation on the theory and effects of the tooth profile of the S series at the ASME International Power Transmission and Gearing Conference.	
	4	Koden Electronics Co., Ltd. took over the former Harmonic Drive Systems Inc., making the new Harmonic Drive Systems Inc. its wholly owned subsidiary.	
	5	President Albert Diamond of HDSys visited the Matsumoto Factory (currently the Toyoshina Factory).	
	9	Held a joint meeting of all the offices of HDSI titled "A Vision for 20 Billion Yen."	
	11	Mitsumasa Ito returned from HDSG and became a Director. Presented the main theme "Our Long-Term Vision for the 21st Century" and sub themes "New Products, the Direction of New Businesses, Sales Strategies, Technical Innovations, and Production Systems, Development of International Strategies, Employee Quality of Life, and Work Environment" for Forum 2001.	
	1990	3	Began the construction of the new Hotaka Factory.
		4	Held the 10th Harmonic Concert celebrating the 20th anniversary - a recital by Mitsuko Shirai (mezzo-soprano), Hartmut Höll (piano), Tabea Zimmermann (viola), and Eduard Brunner (clarinet).
		6	Established the Cooperating Association.
		11	Completed the construction of the new Hotaka Factory.
12		Launched the Toyoshina Factory anew as the Research and Development Center.	
12		Transferred production bases from the Toyoshina Factory to the Hotaka Factory. Shoichi Ishikawa was awarded the Blue Ribbon Medal for his years of research on gears and achievements as an expert committee member on gear standards in the Japan Gear Manufacturers Association. Organized the Fine Positioning System (FPS) team.	
1991		5	Held the 1st Harmonic Drive International Symposium 1991 (at Hotaka View Hotel).
	9	Relocated the Osaka Office to Ebie, Fukushima-ku, Osaka. Relocated the Head Office from Oimachi, Shinagawa-ku, Tokyo to the Recruit Kawasaki East Exit Building in Kawasaki, Kanagawa Prefecture.	
1992	3	Relocated the Yokohama Office from Naka-ku, Yokohama to the Kawasaki Head Office.	
	6	Established the MC Business Promotion Division.	
	9	Reformed the organization of the Production Division.	

Year	Mo.	Events at HDS
1992	9	Relocated the Kanagawa Office from Kawasaki to Shin-Yokohama.
	10	Relocated the Tokyo Office from Kanda to Omori.
	10	Relocated the Head Office from Kawasaki, Kanagawa Prefecture to Minami-Oi, Shinagawa-ku, Tokyo (to the present day).
1993	10	Relocated the Research Center from the Toyoshina Factory to the Hotaka Factory.
	11	Exhibited a booth at the International Robot Exhibition (at the Tokyo International Trade Fair in Harumi).
1994	4	Rented the Toyoshina Factory to Seiko Epson Corp.
	7	Appointed new officers. Chairperson, Representative Director: Atsuo Tokoro, President, Representative Director: Mitsumasa Ito
	10	Held a party for celebrating the completion of the extension of the Hotaka Factory building.
		HDSG changed its company name to Harmonic Drive Antriebstechnik GmbH (hereafter called HDAG, currently HDSE).
1995	9	Exhibited a booth at the International Robot Exhibition (at the Tokyo International Trade Fair in Harumi).
	9	Registered a patent for the IH tooth profile.
	10	Obtained ISO 9001 certification.
	12	Hosted a trip celebrating the 25th anniversary to Hakkeijima Sea Paradise and Tokyo Disneyland (factory).
	12	Held an event celebrating the 25th anniversary - the 1st art contest titled "What I Want a Robot to Do."
		Included "Total Motion Control" in the marketing policy.
		HDSI's products were adopted for the Subaru Telescope of the NAOJ Hawaii Observatory.
1996	3	Hosted a trip celebrating the 25th anniversary to the Izu Nagaoka hot springs (Head Office and offices).
	4	Completed the construction of the new office building of the Hotaka Factory.
	4	Launched the HM project.
	5	Held the 2nd Harmonic Drive <sup>®</sup> International Symposium 1996 (at Hotel Buena Vista Matsumoto).
	10	Held the 1st Harmonic Lecture by Teru Miyamoto (writer) "What You Get from Travel."
	12	Signed a license and technical support agreement with HDAG (currently HDSE).
		Placed a metal sculpture ("SCREEN-CANYON") at the Hotaka Factory, which was later relocated to IIDA-KAN.
1997	4	Held the 1st Harmonic Drive <sup>®</sup> International Conference with HDSI, HDAG, and HDSys (at HDAG).
	5	Held the 15th Harmonic Concert - a recital by Keiko Urushihara (violin), Hirofumi Kanno (cello), and Teruji Karashima (piano).
	7	NASA's Mars Pathfinder landed on Mars, which had Harmonic Drive <sup>®</sup> FR-40 in its solar array driving system.
	10	Held the 2nd Harmonic Lecture by Jun'ichi Nishizawa (former President of Tohoku University) "The Meaning of Creative Technology." Included "Total Motion Control" in the management policy.
1998	3	Got listed in the over-the-counter market.
	4	Obtained ISO 14001 certification.
	5	Held the 2nd Harmonic Drive <sup>®</sup> International Conference with HDSI, HDAG, and HDSys (at HDAG).
	10	Established a website.

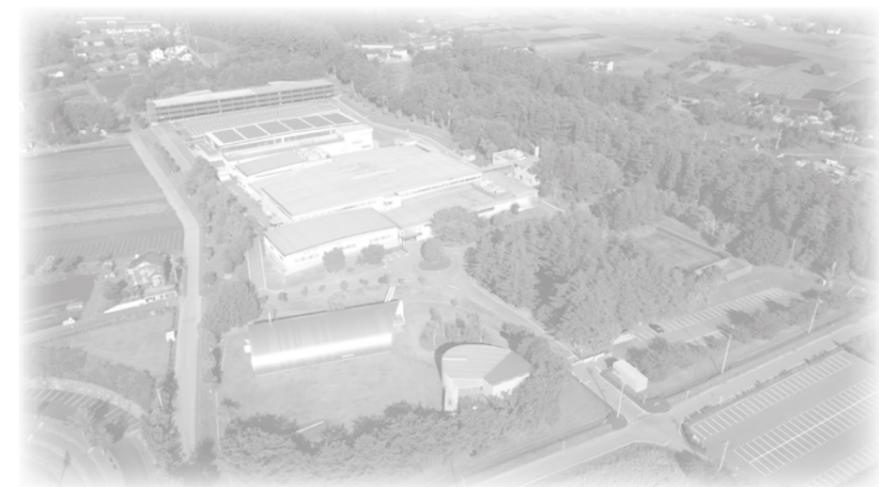
Year	Mo.	Events at HDS	
1998	10	Established the HM project system as fully operational.	
1999	4	Established HD Logistics, Inc. (hereafter called HDL).	
	7	Established Harmonic Precision Inc. (hereafter called HPI).	
	9	Decided to introduce the enterprise resource planning software SAP R/3 (to start operation in 2001).	
	11	Harmonic Drive Antriebstechnik GmbH changed its company name to Harmonic Drive AG (hereafter called HDAG, currently HDSE).	
2000	4	Rented the Toyoshina Factory to Sony Digital Products Co., Ltd.	
	5	Held the 18th Harmonic Concert celebrating the 30th anniversary - a recital by Mitsuko Shirai (mezzo-soprano) and Hartmut Höll (piano).	
	8	Decided to acquire factory premises for HPI.	
	9	Hosted a Chowakai trip celebrating the 30th anniversary to Hokkaido.	
	10	Held the 5th Harmonic Lecture celebrating the 30th anniversary by Teru Miyamoto (writer) "A 6,700 km Journey Along the Silk Road."	
	11	Held a ground-breaking ceremony for the construction of the new HPI building (in the Matsumoto Rinku Industrial Complex).	
		Released the Harmonic Drive <sup>®</sup> CSG series with higher torque capacity onto the market.	
		Honda R&D Co., Ltd. released the bipedal robot "ASIMO," which used HDSI's product.	
	2001	3	Completed the construction of the new HPI building.
		3	Demolished the dome-shaped warehouse of the Toyoshina Factory.
		4	Held a ground-breaking ceremony for the construction of the memorial buildings celebrating the 30th anniversary.
6		Held the 1st factory assessment workshop by Hitoshi Yamada, director of PEC Center of Industrial Education.	
7		Started to operate the new system of the HM II project.	
9		Held the International Marketing & Technical Meeting (at HDAG).	
9	Launched the delivery time shortening project.		
11	Held the 3rd Harmonic Drive <sup>®</sup> International Symposium 2001 (at Hotel Buena Vista Matsumoto).		
2002	4	Completed the memorial buildings (TRIAD) celebrating the 30th anniversary.	
	5	Held the 20th Harmonic Concert - a recital by Tsugio Tokunaga (violin), Noboru Kamimura (cello), and Shigeo Neriki (piano).	
	5	Held a party to celebrate the completion of the memorial buildings (TRIAD) celebrating the 30th anniversary.	
7	Acquired 25% of the shares of HDAG.		
2003	4	Established Harmonic AD, Inc. (hereafter called HAD).	
	5	JAXA's Hayabusa, which had Harmonic Drive <sup>®</sup> in the gimbal mechanism for the ion engines (manufactured by Moog Inc.), was successfully launched (returned to earth in June 2010).	
	5	IIDA-KAN was added to the Azumino Art Line.	
	6	Appointed new officers. Chairperson, Representative Director: Mitsumasa Ito, President, Representative Director: Nobuo Kumagai	
	6	Introduced the executive officer system.	
	9	Relocated the Chubu Office from Nishiki, Naka-ku, Nagoya to Hongo, Meito-ku, Nagoya.	

Year	Mo.	Events at HDS
2003	11	Integrated the Kansai Office and Kyoto-Shiga Branch into the new Kansai Office (Shin-Osaka).
2004	1	NASA's Mars Exploration Rover, which used HarmonicDrive®, landed on the surface of Mars.
	8	HDSI's stock was selected as one of the stocks comprising the JASDAQ J-Stock Index.
	9	Completed the relocation of HAD to the Toyoshina Factory.
	10	The HarmonicPlanetary® HPG series was awarded a Good Design Award.
	12	Got listed on the JASDAQ Securities Exchange.
		The hand system (robotic hands using HarmonicDrive®) created by the Ishikawa Group Laboratory of the University of Tokyo was exhibited at the National Museum of Emerging Science and Innovation.
2005	1	Launched the North American business integration project (a joint business integration project with Nabtesco Corporation).
	2	Signed an exclusive distributorship agreement with Mitsui & Co., Ltd. for sales of HDSI's products in Taiwan.
	3	Signed an exclusive distributorship agreement with Mitsui & Co., Ltd. for sales of HDSI's products in Korea.
	5	Held the 23rd Harmonic Concert celebrating the 35th anniversary - a piano recital by Yuko Fujimura.
	9	Awarded the "2005 IR Company of Excellence" by the JASDAQ Securities Exchange.
	10	Invited Honda's bipedal robot "ASIMO," which used HDSI's product, to the event celebrating the birth of Azumino City.
	11	Hosted a Chowakai trip celebrating the 35th anniversary to Okinawa.
	11	Held the 10th Harmonic Lecture by Yoshiko Sakurai (journalist) "Education Opens the Path to the Future."
	12	Established Harmonic Drive L.L.C. in the United States jointly with Nabtesco Corporation.
	2006	2
4		Yoshikuni Iida passed away.
9		Held a gathering in memory of Yoshikuni Iida.
9		Built the Musser Heritage Room on the premises of the Hotaka Factory.
10		Held the 4th HarmonicDrive® International Symposium 2006 (at Hotel Buena Vista Matsumoto).
2007		5
	5	Received a Best Paper Award of the Japan Society for Design Engineering for the publication of research findings.
	5	Formed a business and capital alliance with Winbel Corporation.
	6	Acquired the shares of HPI owned by Akahane KOKI Inc. (making it a wholly owned subsidiary).
	6	Appointed new officers. Chairperson, Representative Director: Mitsumasa Ito, President, Representative Director: Masakatsu Sasahara
	12	The ultra-small, high-precision, and high-output AC servo actuator RSF-3B won the Organization for Small & Medium Enterprises and Regional Innovation Award of the Robot Awards 2007.
2008	1	Completed the construction of the new factory of Winbel Corporation.
	2	Extended the HPI factory from 1,542m <sup>2</sup> to 2,887m <sup>2</sup> (by a factor of 1.87).
	3	Participated in the exhibition of the Embassy of Germany titled "Germany in Nagano."
	5	Held the 9th International Meeting (at HDSI).

Year	Mo.	Events at HDS
2008	10	Formed a business and capital alliance with Ome Iron Casting Co., Ltd.
	12	Mitsumasa Ito, Chairperson, Representative Director, received the Order of Merit of the Federal Republic of Germany in the Grade of the Cross.
	12	Formed a business and capital alliance with Soft Servo Systems, Inc.
2009	2	Terminated all the distributorship and exclusive agency agreements with Mitsui & Co., Ltd.
	6	Enhanced the partnerships with the factory in Japan and two factories overseas for development, etc.
	10	Reorganized the Precision Equipment Division and Mechatronics Division into the Production Division and Development Division.
2010	10	Built a case management system by utilizing ECMMASTAR.
	10	Held the 28th Harmonic Concert celebrating the 40th anniversary - a recital by Mitsuko Shirai (mezzo-soprano) and Hartmut Höll (piano).
	11	Held concurrently a special exhibition celebrating the 40th anniversary "TRIAD Yoshikuni Iida and Fumihiko Maki Joint Exhibit" and a special exhibition for the 5th anniversary of the death of Yoshikuni Iida in April 2011.
	11	Held an event celebrating the 40th anniversary - the 2nd art contest titled "My Kind of Robot."
	11	Held a party to celebrate the 40th anniversary (at Hotel Buena Vista Matsumoto).
2011	1	Established Harmonic Drive Systems (Shanghai) Co., Ltd. (hereafter called HDCH) in China.
	2	Purchased premises to build HPI's factory for the blanking process.
	6	Appointed new officers. Chairperson, Representative Director: Mitsumasa Ito, President, Representative Director: Haruo Wakumoto
2012	1	Received an Award of Merit 2011 from Azumino City.
	1	HAD started its new system for planetary gear business.
	3	Hosted a Chowakai trip for supporting the revitalization of tourism in Tohoku.
	11	Relocated the HDCH office.
	11	The works of IIDA-KAN were exhibited at the Azumino Art Line Exhibit held at the Alps Azumino National Government Park.
2013	2	Established SAMICK ADM CO., LTD., a joint venture in Korea.
	6	Appointed new officers. Chairperson, Representative Director: Mitsumasa Ito, President, Representative Director: Akira Nagai
	10	Held the 30th Harmonic Concert - a recital by Tsugio Tokunaga (violin) and Eri Hayashi (piano).
2014	1	Received an Award of Merit 2013 from Azumino City for contributing to the promotion of social education activities by holding a series of Harmonic Concerts.
	9	Family members of C. Walton Musser visited Japan (visited the Head Office and Hotaka Factory).
	11	Held the 15th Harmonic Lecture by C.W. Nicol (Author, Naturalist) "Harmony of Human and Nature."
	12	JAXA's Hayabusa2, which had HarmonicDrive® in the gimbal mechanism for the ion engines (manufactured by Moog Inc.), was successfully launched (the capsule returned to earth at the end of 2020).
2015	4	Atsuo Tokoro, former Chairperson, Representative Director, passed away.
	5	Held the 5th HarmonicDrive® International Symposium 2015 (at Hotel Buena Vista Matsumoto).
	7	Held the 32nd Harmonic Concert celebrating the 10th anniversary of the municipal system of Azumino City - a piano recital by Yuko Fujimura.

Year	Mo.	Events at HDS
2015	7	Extended the retirement age to 65.
	11	Hosted a Chowakai trip celebrating the 45th anniversary to Kyoto, Osaka, and Kobe.
	11	Shoji Hata, Adviser, passed away.
2016	2	Akira Arakawa, Advisor, passed away.
	4	Completed the construction of the new building of the Hotaka Factory. Raised the monthly production to 80,000 units.
	5	Kishi, Advisor, received the JSDE Award from the Foundation for Cornerstone of Design to commemorate of 50th Anniversary.
	7	Established the representative office in Taiwan.
	10	Held the 17th Harmonic Lecture by Junichiro Koizumi (Former Prime minister) "Path Japan Should Take."
	10	Installed solar power panels on the roof of the new factory.
2017	3	Additionally acquired 63.2% of the issued shares of the German affiliate HDAG jointly with the Innovation Network Corporation of Japan, making it a jointly owned subsidiary.
	3	Acquired factory premises for HPI's new factory at the New Matsumoto Industrial Park.
	6	Held an opening ceremony for the HDSys Silicon Valley Office.
	7	Received the "2017 Best Robot Parts Award" at the 6th China International Robot Show.
	8	Selected as one of the stocks comprising the JPX-Nikkei Index 400 in 2017.
	12	Acquired factory premises in Hotakaariake, Azumino.
	12	Began the construction of the HPI Matsumoto Factory.
	12	Selected as a "Company Driving Regional Growth" by the Ministry of Economy, Trade and Industry.
2018	3	Started operation of the Ariake Factory.
	4	Closed the Kitakanto Office and integrated it into the Tokyo Office.
	5	Relocated the MT Development Department to the Ariake Factory.
	6	Held the 35th Harmonic Concert - stories about the horn and a recital by Soichiro Ohno (horn) and Yasuo Watanabe (piano).
	7	Kiichiro Hasegawa, founder, passed away.
	7	Received the Nissan Global Supplier Award - Global Innovation Award from Nissan Motor Co., Ltd.
	8	Selected as one of the stocks comprising JPX-Nikkei Index 400 in 2018.
	8	Family members of C. Walton Musser visited HDAG.
	9	Began the construction of the new Ariake Factory.
	10	Participated in the World Robot Summit (WRS) 2018 as one of the Official Partners (at Tokyo Big Sight).
	11	Shoichi Ishikawa was awarded the Academic Experts Award of Merit of the Japan Gear Manufacturers Association.
2019	2	Completed the construction of the new Matsumoto Factory.
	3	Extended the retirement age to 70.
	4	Relocated the Tokyo Office from the 2nd floor to the 4th floor of the same building.
	5	Held a lecture by Katsuaki Watanabe, former president of Toyota Motor Corporation (at the Hotaka Factory).

Year	Mo.	Events at HDS
2019	5	Decided on the symbol logo mark and slogan for the 50th anniversary.
	8	Selected as one of the stocks comprising JPX-Nikkei Index 400 in 2019.
	8	Held the 6th HarmonicDrive® International Symposium 2019 (at Plaza Heisei, Tokyo International Exchange Center).
	9	Completed the construction of the new Ariake Factory.
	9	Joseph Ranger, former President and Representative Director, passed away.
	10	Held the 20th Harmonic Lecture by Sadayuki Sakakibara (honorary chairman of the Japan Business Federation) "The Path toward Revival of the Japanese Economy."
2020	1	Held an opening ceremony for the new factory of HDLLC (in Beverly, MA).
	1	HDAG changed its company name to Harmonic Drive SE with "SE" indicating a European Company.
	2	Implemented measures against the outbreaks of COVID-19 (created a task force).
	5	Relocated the Head Office from the 7th floor to the 4th floor of the same building.
	6	Hiroshi Kameda, former Technical Advisor, passed away.
11	Celebrated the 50th anniversary.	



## Editorial Note to the Fifty-Year History

We are pleased to publish the Fifty-Year History, which we have been compiling as part of the project celebrating the 50th anniversary.

In February 2017, three years before the 50th anniversary, the Company History Compilation Room was launched and started its activities.

Based on our belief that clarifying the history, roles, and direction of the organization and confirming its significance and uniqueness would help employees improve their loyalty and motivation and benefit employee education, we defined the objectives for compiling the company history as follows: To organize and save the materials, personal memories, and records scattered inside and outside the company seizing on the anniversary; To provide great encouragement to junior colleagues by letting them learn the history and expertise of senior colleagues because the significance of learning history is to understand the causes of successes and failures and apply that understanding, and to contribute to the development of society and industry by donating it to libraries, etc. as a research material on industrial history.

The history of HDSI started with the prehistory of an encounter with HarmonicDrive® speed reducers and introduction of the technology to Japan, rather than the establishment of the company. We decided to include the entire 50-year history of the company since its establishment, including the years of Hasegawa Gear Works during which HarmonicDrive® technology was introduced, and compile a comprehensive 50-year history by taking an inventory of events as the company reaches its half-century milestone. We divided the historical events and the technological history into separate sections, and tried to make them easy to read by using less text and more visuals so that they could be used for employee education and as materials on the industry.

Although there existed is a 10-year history and 20-year history, no history has been compiled since then. We started with by creating an information ledger to be used as a basis.

While employees with no knowledge of the past of HDSI were increasing every year, we interviewed alumni of the company who knew the past, and included their anecdotes. We also videotaped the interviews, which are available on DVD.

To create a tool for educating current employees about the specific history of HDSI rather than an anniversary history book with historical facts and photos that sits on the shelf unread, we interviewed the early employees about the early years and borrowed valuable photos from the alumni. While we interviewed many alumni, current officers, and employees to collect valuable stories, we regret that we could not include many of them because of space limitations. Please accept our sincere apologies.

The anniversary history consists of the Fifty-Year History and Technological History. In the Technological History, we described the development and expansion of the HarmonicDrive® speed reducers with behind-the-scenes stories about the development so that it could be used as materials on industrial history.

We hope the company history will serve as a guidebook for employees who bear the future of HDSI. We would be grateful if people read this company history to overcome future difficulties in 10 or 20 years' time.

Lastly, I would like to take this opportunity to express my gratitude to our business partners who helped us in the compilation, officers, employees, and alumni who provided materials and cooperated in interviews, people from Shuppan Bunka Sha Corporation, who helped us tremendously in planning, writing, editing, and production, and the members of the Compilation Room who did their best in completing the company history.

Hiroshi Ozawa  
Director of the Company History Compilation Room

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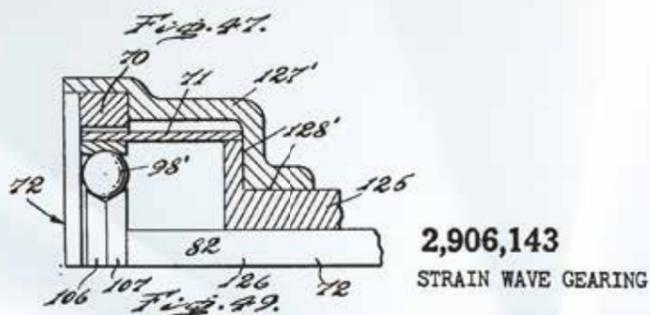
**Our Journey**

DOUTEI

**The Fifty-Year Progress of *Harmonic Drive Systems Inc.***

**Technological History**

# Technological History



2,906,143  
STRAIN WAVE GEARING

- 1955 -



INVENTOR.  
*C. Walton Musser*  
[ 1909-1998 ]



- 1965 -



- 2020 -

Pioneering the Future with Technologies and Skills

FINE MECHANICS & TOTAL *Motion* CONTROL

## We Offer the Fruits of Our Outstanding Technology

HarmonicDrive® is a unique strain wave gearing. It is widely used in many areas, including robots, semiconductor manufacturing equipment, factory automation equipment, as well as aerospace applications that fulfill the dreams of humankind. Our mechatronics products create highly precise motion. HarmonicDrive® play a critical role in industry, science, and technology, such as optical measuring instruments, medical devices, and printing machines. Harmonic Drive Systems Inc. will contribute to the global advancement of technology in the future, develop technologies that serve as the backbone of the 21st century, and keep moving forward.



**HarmonicDrive®**  
*The Hallmark of Hi-Precision*



How Harmonic Gearing Works

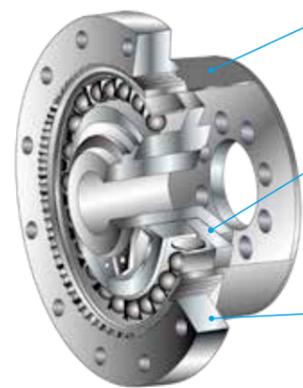
## Feature

- High rotational accuracy and positioning accuracy
- Compactness and light weight
- High reduction ratios
- High torque capacity
- No backlash
- High efficiency
- Quiet operation

## Structure

The HarmonicDrive®, a strain wave gearing, which utilizes unique operation principles based on the elastic mechanics of metals, consists of just three basic components: a wave generator, a flexspline, and a circular spline. It has superior characteristics that no other gearing has.

Structure of the HarmonicDrive® unit (component type)



### Flexspline

A thin-walled elastic steel cup with teeth machined into the outer surface of the opening. The bottom of the flexspline is called the diaphragm. It is usually attached to the output shaft.

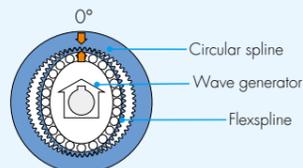
### Wave generator

An elliptical-shaped component with a thin-raced ball bearing pressed around the elliptical cam. The inner ring of the bearing is fixed to the cam, while the outer ring elastically deforms via the balls. It is usually attached to the input shaft.

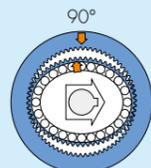
### Circular spline

A rigid steel ring with teeth on the inside diameter. The size of the teeth is the same as that of the flexspline. It has two more teeth than the flexspline. It is usually attached to the housing.

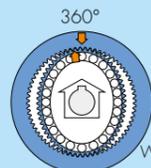
## Principle of Operation



The three basic components are combined. The flexspline is elliptically shaped by the wave generator. The teeth of the flexspline mesh with the teeth of the circular spline across the major axis of the ellipse, and completely disengage across the minor axis of the ellipse.



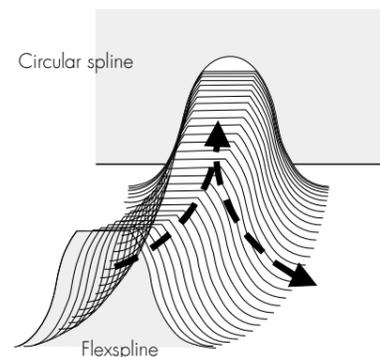
When the wave generator (input) rotates clockwise with the circular spline fixed, the flexspline elastically deforms, and the points where the teeth mesh move sequentially.



As the wave generator rotates one revolution, the flexspline moves counterclockwise by two teeth because it has two fewer teeth than the circular spline. Usually, this motion is taken out as output

## Movement and Meshing of Gear Teeth

HarmonicDrive® offers small angle feeding (following single pulse feeding) and superior positioning accuracy with no backlash due to its special teeth movement (operation principle) unlike the movement of common gears. Because more than 30% of the teeth mesh simultaneously at the two opposing points, high torque transmission is possible.



## 1-1 | Invention of C. Walton Musser

A technological invention rarely appears out of the blue. Most of the time, such an invention is based on preceding inventions. HarmonicDrive® is no exception. One example of a pioneering invention is a British patent by the US engineer named Otto Rudolf Gischow in 1925. This mechanism consisted of two circular disc gears with different numbers of teeth that were brought into a mating relationship to obtain slow relative rotation of the gears due to the tooth differential by pressing the thin and flexible gear against the thick gear with a contact piece and rotating the contact piece to shift the tooth engagement position (Figure 1).

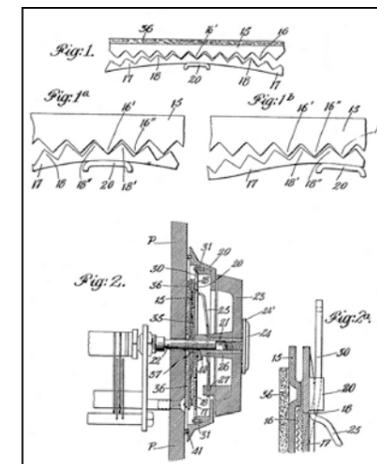


Figure 1

Another example of a pioneering invention is a British patent by the British engineer named Ernest Hoyle in 1930. He devised a mechanism in which the inner circumference of the stationary thin cylinder was slightly greater than the outer circumference of the cylindrical portion of the inner knob fitted into it, which were brought into contact via three rollers attached to the outer knob. This invention is considered a prototype of HarmonicDrive® in the sense that it uses a flexible thin cylinder, but it uses

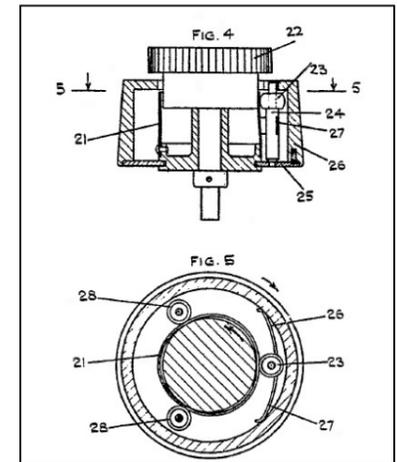


Figure 2

friction transmission instead of the mating of the teeth (Figure 2).

These inventions preceded HarmonicDrive®, but this fact does not lessen the significance of the creativity and outstanding idea of the product's inventor C. Walton Musser. The preceding inventions were, so to speak, in the germination stage. Musser should be given credit for throwing a new light on them, recognizing their vast possibilities, and bringing them into reality.



Musser working in his home laboratory

HarmonicDrive® was developed at USM (the United Shoe Machinery Corporation) in the United States in the mid-1950s. C. Walton Musser, who invented it, was a research advisor to the Department of Defense for 15 years. He was a genius inventor credited with over 250 major inventions and discoveries, including the recoilless

rifle, aircraft personnel catapults, and instrumentation for underwater detonation testing. When he invented HarmonicDrive®, he was a research adviser to USM.

A patent for the invention of HarmonicDrive® was filed as “Strain Wave Gearing” in the United States in 1955, and registered as a U.S. patent in 1959.

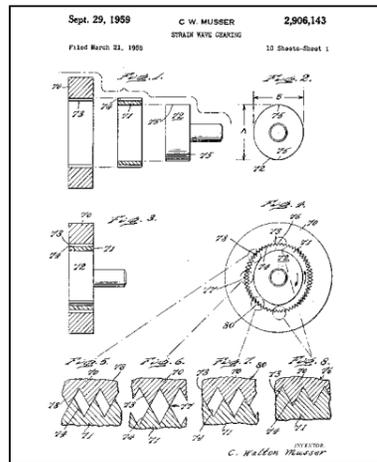


Figure 3

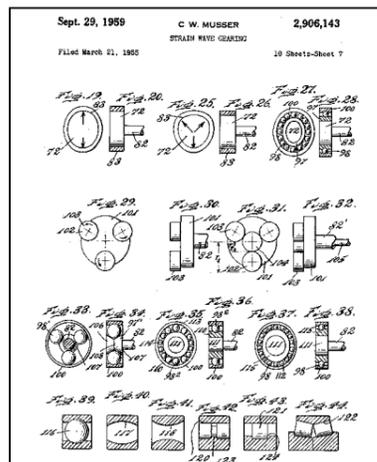


Figure 4

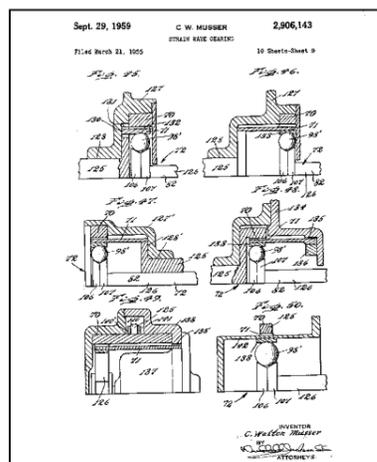


Figure 5

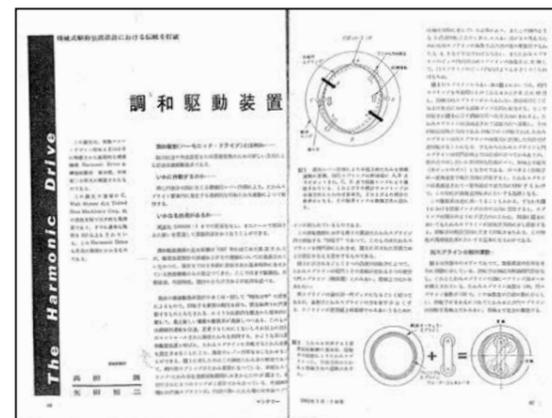
Figures 3, 4, and 5 are the drawings included in the patent specification. The patent was the starting point of the current HarmonicDrive®.

In April 1960, an American mechanical engineering magazine *Machine Design* carried an article contributed by Musser. The article detailed its mechanism, principles of operation, and characteristics, with many application and design examples.

From January to April 1961, a Japanese magazine *Machinery* carried articles based on the translation by Messrs. Takada and Yada at the Mechanical Laboratory at the time, which made it well-known in Japan.



Machine Design



Machinery

In the former Soviet Union, *Vestnik Mashinostroenia* carried a summary article in 1962. Based on his unique invention, Musser and the engineering team of USM put tremendous efforts into the development of a practical product.

Basically, HarmonicDrive® consists of the following three components:

- (1) Wave generator, which has an elliptical shape and a ball bearing

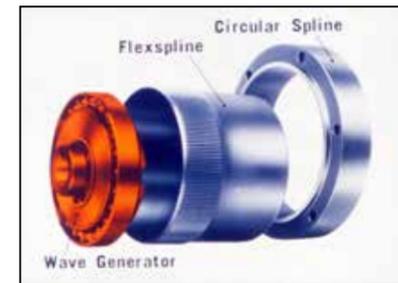


Figure 6

- (2) Flexspline, which is a thin-walled flexible steel cup with teeth machined into the outer surface

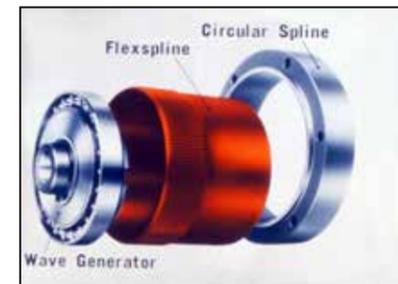


Figure 7

- (3) Circular spline, which is a rigid steel ring with teeth on the inside diameter.

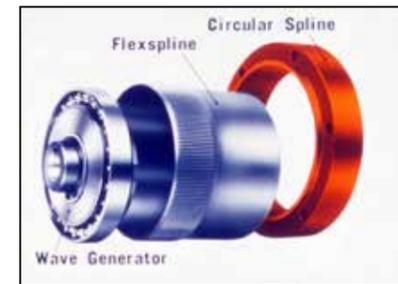


Figure 8

Specifically, as the wave generator inserted inside the flexspline rotates one revolution clockwise, the flexspline deforms elastically, and moves counterclockwise by two teeth relative to the circular spline.

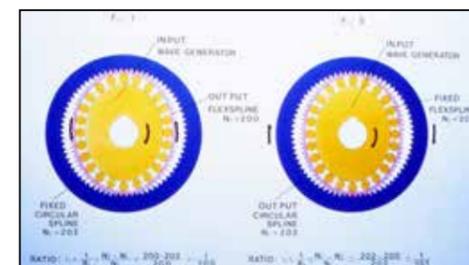


Figure 9

- This structure achieves the following characteristics:
  - High reduction ratios obtained with a single stage
  - High torque capacity
  - Extremely low backlash
  - High efficiency despite the high reduction ratios
  - Extremely low gear tooth sliding
  - Easy to achieve a unique structure that allows for a fully sealed mechanism

## 1-2 Technology Introduction by Hasegawa Gear Works

Hasegawa Gear Works and USM signed a technology introduction agreement in June 1964. The agreement pertained to the basic theory, principles, design method, stress calculation method, material and quality management methods related to the HarmonicDrive® mechanism, samples, specifications, performance, characteristics, actuation techniques, design specifications, fabrication methods, inspection and testing methods, and engineering of general market products, and manufacturing techniques including elliptical grinding equipment.

In November 1964, the Japanese government formally approved the “HarmonicDrive® license agreement.” In January 1965, a technical training was conducted at USM. A team of four, namely Vice president Kiichiro Hasegawa, Manager of the Development Department Hiroshi Kameda, Chief of the Engineering Section Shoichi Ishikawa, and Chief of Production Engineering Mitsuo Arita, participated as the “HarmonicDrive® Technical Training Team”. They collectively learned all aspects of the technology, including the principles of HarmonicDrive®, patents, strength calculation, design methods, fabrication methods, and inspection and measurement methods.

Shoichi Ishikawa gave an anecdote about the flexibility of the flexspline as the highlight of the technical training.

“During a lecture, Musser took out a metal cup with a stick that was slightly longer than the inside diameter pinched across the opening. He told us to deform the cup with our fingers to let the stick fall to the bottom of the cup. We tried our best assuming that pressing the edges

of the cup perpendicular to the stick to make it slightly elliptical would do the trick, but did not succeed. Musser said, "Let me try" and took the cup. He pressed the edges of the cup gently, and the stick fell to the bottom of the cup without difficulty. Then, he showed us the trick. It was the thickness of the bottom of the cup. If the bottom of the cup was thick enough, squeezing the cup in the diametrical direction would deform the cup in the 45 degree direction to form a rectangle. If the bottom was thin, doing so would form an ellipse. The diaphragm of HarmonicDrive®, serving as the bottom of the cup, had to be thin in essence. At the same time, it had to easily withstand the output torque. The structure of the diaphragm required careful consideration."

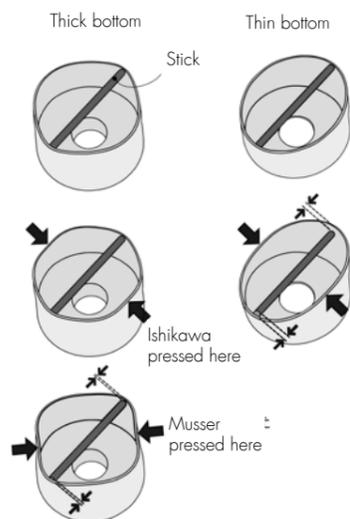


Figure 10

Having discovered a contradiction with this invention, Shoichi Ishikawa asked a direct question to Musser between lectures. What he thought was a contradiction was the movement trajectory of the teeth of the flexspline with respect to the circular spline as illustrated in the specification. He couldn't convince himself that the teeth of the flexspline could move along a sinusoidal curve as shown in the drawing. He also questioned the basis for the pressure angle formula for the flexspline.

Answering the question of Shoichi Ishikawa, Musser immediately said "This is wrong." He jokingly said, "The officers at the patent office have a rigid way of thinking. I drew it so that people with rigid thinking would under-

stand."

On October 20, 1965, 9 months after the technical training, Shoichi Ishikawa invented "HarmonicDrive® with the contact position shifted to the tooth flank," which was registered as a patent on February 24, 1970, and later named "Shifted HarmonicDrive®" and applied to many of HDSI's new products. It was also presented at the International Symposium of the Japan Society of Mechanical Engineers in 1967.

On October 24, 1991, it was described as noteworthy

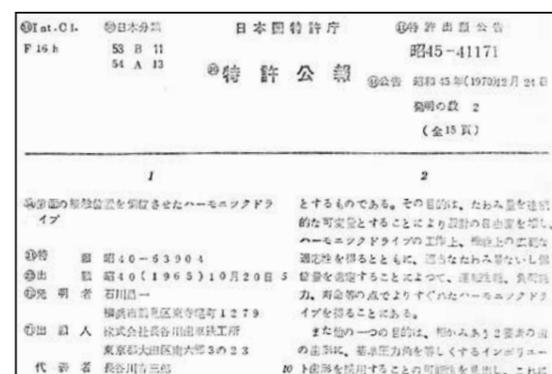


Figure 11 Patent application for HarmonicDrive® with shifted contact position on the tooth flank

in this area at the technical lecture "HarmonicDrive® - Towards the Ultimate" held by the JSME section meeting RC97.

### 1-3 Production of the First Domestically Produced Unit

After the Technical Training Team came back to Japan after the training, Hasegawa Gear Works took the first step toward the commercialization of the domestically produced HarmonicDrive®. In fact, the company succeeded in prototyping on December 11, 1964, before sending out the team. This was before they obtained specific design drawings, design methods, and expertise from USM. As a result of working on prototyping to acquire background knowledge before the technology training as the Technical Training Team and to modify the manufacturing equipment for Hasec worm speed reducers, they

succeeded in just one and a half months.

With the technical foundation, the manufacturing of the first standard product, which was started after the technical acquisition, went smoothly. The first domestically produced unit, Size 100 and reduction ratio of 1/96, was manufactured for Hitachi, Ltd. as a speed reducer for a bending roller. It was delivered in late August, 1965.

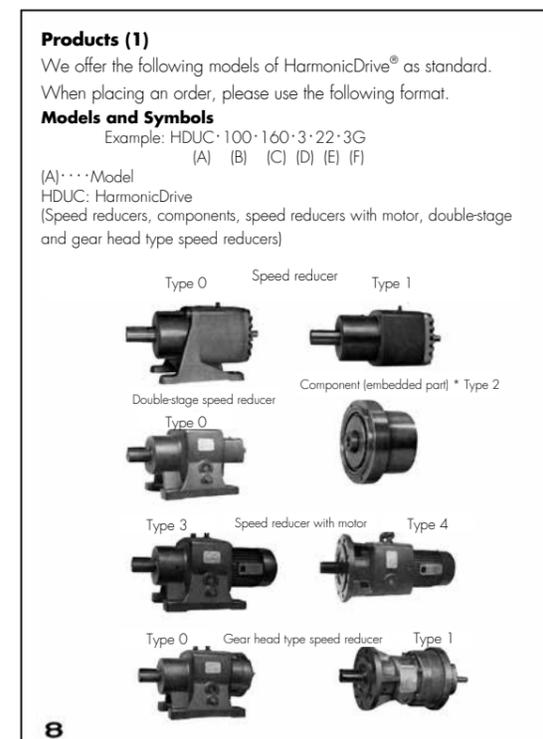


Figure 12

Around that time, the company received an increasing number of requests for quotation with the size and reduction ratio specified from users who wanted to try it out. As of August 8, the company had already received orders for 84 units.

### 1-4 Start of Mass Production

At the time of the technology introduction, USM had a PR publication *ILLUSTRATED APPLICATIONS*, which included drawings of different types of wave generators, flexsplines, and circular splines as well as many applications of components using them in combination and their descriptions. The most mature type at the time of the technology introduction was the cup type. Taking

into consideration its own commercialization capability, Hasegawa Gear Works started the mass production of the type as a standard series. There were 8 sizes from Sizes 20 to 100 (10 times the pitch diameter (in inches) of the flexspline gear) as in the standard of USM. In 1965 and onwards, Hasegawa Gear Works standardized Type 2 of the component standard type, two models of speed reducers with input/output shaft, the double-stage speed reducer, two models of HarmonicMotor® with induction motor, and two models of gear head type speed reducers in sequence. In 1967, the products as shown in

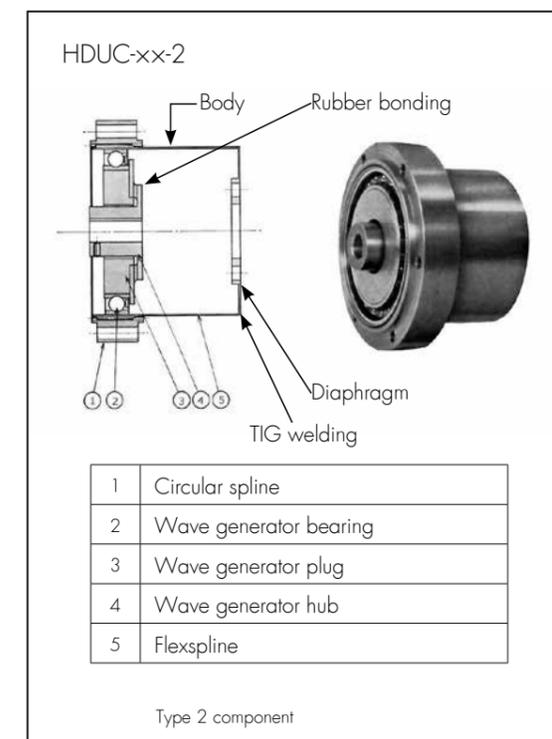


Figure 13

Figure 12 were available. Later, Hasegawa Gear Works added Harmonic Coupling as a standard product. The Type 2 or semi-standard Type 2A component was used for speed reducers and HarmonicMotor®. The flexspline of the standard Type 2 component had a stainless-steel thin circular disc that was TIG welded to the body of the stainless-steel thin pipe. This structure allowed for easier manufacturing when the mass production was started.

The component with this structure caused a variety of technical challenges in the later applications.

At the beginning of the mass production, the models were indicated with four alphabetic characters as in HDUC-100, as in the standard notation of USM.

[Example]

**HDUC: HarmonicDrive®**

**HDUI: Harmonic Coupling (phase adjustment coupling)**

**HDUP: Plastic HarmonicDrive®**

**HDUH: Sealed type speed reducers**

The first three characters “HDU” (HarmonicDrive®) remained the same, while the fourth character varied depending on the model. At USM, RESPONSYN (electromagnetic) was indicated with three characters “HDM” as an exception.

HDSI used this notation from the start of the mass production until 1972. As the number of models increased as a result of the commercialization of its own new models, HDSI stopped using the common notation of “HDU” and started using the first one or two characters to indicate the model. Two characters were used for types of HarmonicDrive® components which included many models.

[Example]

**CS: Cup type (C) single-stage speed reducers**

**CD: Cup type double-stage speed reducers**

**CG: Gear head type**

**FB: Flat type ball bearing wave generator (B)**

**FH: Flat type manual input low speed input**

**J: Harmonic Coupling (phase adjustment coupling; Product name: JUST)**

**HDM: RESPONSYN (notation by USM)**

The notation after the change will be used in Chapter 2 and onwards. Later, HDSI started using three characters because of marked improvements in strength and accuracy for the same shape of the HarmonicDrive® component as a result of the development of new technologies such as the invention of a new tooth profile.

## 1. HarmonicDrive® Products

### 2-1-1 | Development of the Cup-Type CS Series (Size Nos. 20 to 100)

#### Beginning of Development

The domestic production of HarmonicDrive® started with the cup-type standard product series. In Japan, there were few requests for the catalog standards. Most requests were related to special drive units (2-1-4) with components utilizing the characteristics including compactness, light weight, and high reduction ratio as requested by the customer.

*ILLUSTRATED APPLICATIONS* contained many drawings of similar devices, but USM had no record of sales. The demand in the Japanese market was diverse. The standard specifications resulted in abnormal phenomena and failure during operation due to unexpected operating and environmental conditions. The improvements and measures for the cup type to resolve the problem marked the beginning of development.

#### Technology Overview

There were two types of flexspline subject to the technology introduction: Type 2 and Type 2A. Type 2 with a welded stainless-steel construction was positioned as the standard from a productivity perspective. The material of the Type 2A flexspline was nickel chromium-molybdenum steel. With a body and diaphragm that were integrated, the type was positioned as a heavy-duty type.

The Type 2 component was mainly used for special-purpose drive units. However, there were many problems, such as not being able to ensure sufficient strength of the welded portion under specific load conditions or device construction, as well as low precision and high variation

due to deformation during the welding process. To ensure strength and precision, the company continued research and development in terms of technology and production engineering, but failed to resolve the problem. As a result, Type 2A was gradually used more often, and Type 2 was later discontinued.

During the process of taking improvement measures for Type 2, the stainless-steel flexspline, the company successfully accumulated advanced technology in mold fabrication.

One of the noteworthy technologies arising from the problems in the applications of the time was the major change of the structure of the standard wave generator of USM. The structure at the time of technology introduction incorporated an aligning mechanism with elastic rubber to compensate for tilt and eccentric error of the joint between the input shaft side of the motor and the wave generator plug. The so-called rubber bonding method placed vulcanized rubber between the iron member (hub) attached to the input shaft (motor shaft) and the iron member (plug) on the wave generator side, and bonded the rubber surface and iron member surface with an adhesive (Figure 1).

This structure caused frequent occurrence of failures due to damage to the rubber-bonded portion in special-purpose shutter actuators. As a result of an investigation, it was found that the rubber surface and iron member surface were separated because the adhesive was degraded by grease components suitable for low- to high-temperature environments that were selected for outdoor operating conditions in all seasons, resulting in failure of power transmission. In the durability test conducted in the devel-

opment stage including outdoor high-temperature conditions, the target duration was satisfied. The phenomenon above progressed over a long period of operation. As a temporary measure, the product was supplied with metal pins added to enable power transmission. As a permanent measure, the company tested the Oldham-type wave generator, which was developed by USM around that time. Because there was significant wear on the pawl, the company developed its unique Oldham-type wave generator. In 1974, this wave generator allowed the company to transition from the rubber bonding method to a mechanism unaffected by lubricant components or temperature change. This structure is still used for the standard products of Size Nos. 8 to 100 (Figure 2).

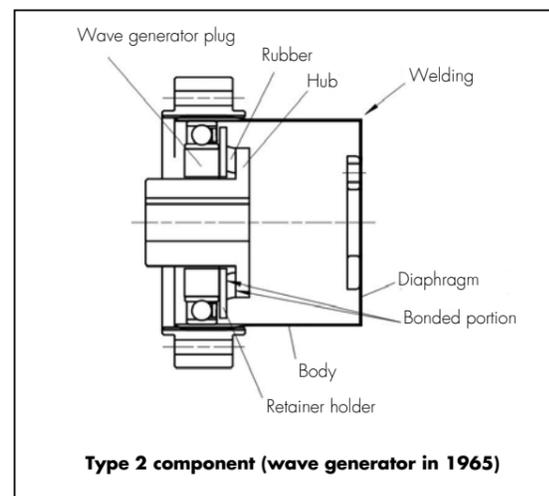


Figure 1

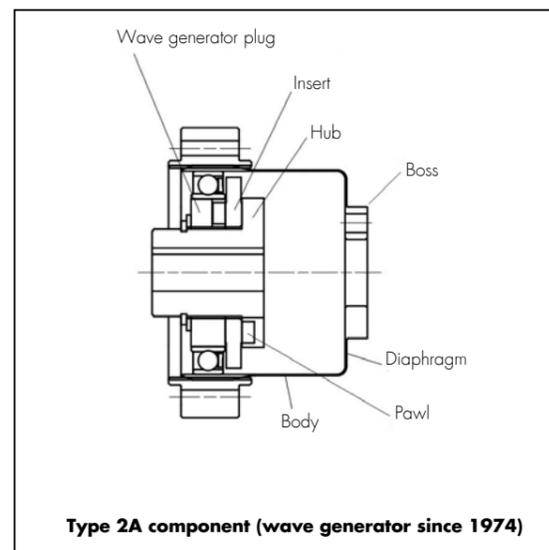


Figure 2

### Commercial Applications

As described in Chapter 1, the company delivered the first domestically produced HarmonicDrive® to Hitachi in August 1965. As a result of its advertising efforts, the company initially received orders for 84 units, which were adopted in a variety of markets, including special-purpose applications as described in 2-1-4.

### Product Lineup

In 1966, the year following domestic production in 1965, the company introduced sizes over 100, i.e., Size Nos. 130, 160, and 200, to the market. The large sizes are described in the next section (2-1-2).

Around 1970, the company started to develop products to meet the demand for sizes smaller than Size No. 20. The lineup of small sizes is described in 2-1-3.

To meet the demand for intermediate sizes of Size Nos. 20 to 100, the company developed and supplied Size Nos. 45, 58, and 90 as special products, and added them successively as standard products.

The amount of backlash is an important characteristics of gear speed reducers. One of the major features of HarmonicDrive® is reduced backlash.

In the early days of domestic production, the amount of backlash was specified to be 1.7 to 6 arc-min. Because of increased demand for specifications with low backlash for devices requiring precise positioning and industrial robots, the company commercialized the BL3 series with guaranteed backlash of 3 arc-min or less as semi-standard products. The backlash of gear meshing was reduced to zero. However, a minute amount of torque is applied to the output side when measuring the amount of backlash. This causes a minute amount of torsion due to elastic deformation of the gear meshing, which is unique to HarmonicDrive®. Therefore, the phrase “zero backlash” is not used.

Later, to meet the demand for specifications with low backlash including a minute amount of torsion, the company developed the BL1 specification with a guaranteed backlash of 1 arc-min or less. With improved machining accuracy and combination machining, the company

offered the BL1 specification as special-specification products.

In addition, the company provided the torque-torsional angle diagram, including backlash and torsion in the minute torque region up to the rated torque region, as wind-up curve characteristics. This was done in response to the wrong impression that HarmonicDrive® had low rigidity due to its thin cup-shaped flexspline. The data indicated that the stiffness was actually similar to that of other speed reducers because of the cylindrical body of the flexspline and disk-shaped diaphragm. It was later quantified as spring constants in different torque regions and provided in catalogs.

BL1 was later used as the basis for the HarmonicDrive® R series for robots.

As a side note, “BL” has been changed to “lost motion (LM),” a performance indicator specific to HarmonicDrive®. This was because there was no expression in the field of gear speed reducers for indicating the amount of torsion caused by applying a small amount of measuring torque while the backlash of gear meshing was virtually zero. The lost motion value was defined as the amount of torsion on the output shaft side when 3-5% of the rated output torque was applied to the output shaft with the input shaft fixed. The word “lost motion” was used as a defined term related to NC equipment, and some experts disputed how the word was used because it was not strictly correct in the field of gears. However, as HarmonicDrive® became recognized as speed reducers for precision control, it took root and started to be used by other companies as a performance indicator for precision speed reducers.

## 2-1-2 Development of the Large Size (Size Nos. 130 to 200)

### Beginning of Development

Hasegawa Gear Works manufactured large gears and had market applications for conveyors of iron manufacturers and steel sheet manufacturers, which required high

torque that could not be achieved by the size of Size No. 100 subject to the technology introduction. Based on the introduced technology, the company developed three high-capacity sizes, Size Nos. 130, 160, and 200.

### Technology Overview

The company started the development mostly by proportional design based on the technology introduced from USM, introduced them to the market in 1966, and added them to the catalog as high-output speed reducers (Figure 3).



Figure 3

Initially, the company built a record of delivery for new applications. However, unlike Size No. 100 or below, a series of failures occurred, such as:

- (1) **Fatigue fracture of the gear tooth roots of the flex-spline**
- (2) **Fracture of the inner and outer rings of the wave generator bearing**
- (3) **Loud noise**
- (4) **High increase in temperature**

As countermeasures against the above, the company kept supplying the products by making improvements such as thermal treatment, material testing, and double eccentric wave generators, but could not resolve them. In 1971, the company discontinued all the three sizes.

### Commercial Applications

The models were adopted for applications including coil conveyors and scale conveyors, shearing lines for thick plates, and turning rollers used by iron and steel sheet manufacturers. Other applications included container transfer and radiation therapy equipment.

## Product Lineup

To meet the demand of specific customers, the company introduced special-specification products, such as the gear head type with the gear speed reducer attached to the input shaft, the ceiling-mounted type, and models with a brake.

## Other Highlights

For a period of time after the discontinuation, the company manufactured speed reducers with the same reduction ratios as HarmonicDrive® using a combination of spur gear trains as substitute products to ensure a secure supply. The countermeasure took advantage of the gear technology of Hasegawa Gear Works. However, because they were not perfect substitutes, the company had to supply parts for the large sizes of HarmonicDrive® for several years as a corporate responsibility, and therefore maintain the facilities for the large sizes.

## 2-1-3 Development of the Downsized Products (Size Nos. 17, 14, 11, 8, 5, and 3)

### Beginning of Development

Around 1970, special applications of sizes smaller than Size No. 20 were created in Japan and Europe. As a result, the company considered Size Nos. 16 and 14, and decided to develop Size No. 14. According to diversified requirements, the company concurrently considered the stainless steel-type and plastic-type, as well as the dual roller-type and planetary roller-type wave generators in addition to the standard type. In 1972, the company created the stainless-steel standard Type 2 component (CS-14-2). The products were used for special-purpose devices and actuators, but the company did not ongoingly seek new applications.

### Technology Overview

After introducing CS-14-2 to the market, HDSI received a request for the same size for aircraft-related applications. In response to the request, HDSI developed Type 2A with an alloy steel flexspline whose body and diaphragm were integrated to ensure reliability, and delivered it as a spe-

cial-purpose unit. Because CS-14-2A was adopted over a long period of time, HDSI made it a standard size in 1978.

### Product Lineup

After introducing Size 14 to the market, HDSI aimed to develop new applications in the small equipment market. While USM had commercialized Size 10 at the time, HDSI introduced Sizes 11 and 8 to the market in 1982, and Size 5 in 1985, considering the balance between sizes and output torques in the series. All of them were Type 2A.

In 1986, HDSI developed Size 4 in response to demand for speed reducers with an outside diameter of 14 mm or less for in-pipe inspection devices, and delivered it as a special-purpose unit in 1987. While delivering 200 units in two years, HDSI decided not to standardize it because no advantage was found as a result of comparing the demand and investment for stable production.

Later, in response to demand for intermediate sizes between Size 20 and Size 14, HDSI introduced Size 17 to the market in 1989. During this period, new applications for small equipment and facilities with compactness and higher accuracy were developed in the market as well as applications in the measuring instrument market.

Around 1978, the small sizes of Sizes 14 to 25 started to be used for actuators of mechatronics products, resulting in a certain level of sales except for Size 5.

Size 5 developed in 1985 was the smallest size at the time, but HDSI was struggling to find new applications as speed reducers. However, its use in the linear actuators of mechatronics products created new markets. This situation is described later in “Mechatronics Products.”

### Other Highlights: Development of the Ultra-Small HarmonicDrive Size 3

The smallest size as of 2020 is Size 3. The background to its market introduction stretches back to 2000.

Professor Makoto Kaneko (at the time) of Osaka University, who had a relationship with HDSI, said that Ishikawa Group Laboratory of the University of Tokyo was looking for compact speed reducers. HDSI visited the

laboratory with the HarmonicDrive® Size 5, the smallest size at the time.

Ishikawa Group Laboratory was working on research on high-speed, high-precision motion control technology for controlling motors based on the feedback from vision sensors by using a robot arm with a hand. A linkage-driven robotic hand was attached to the end of the robot arm. The finger joints had backlash, preventing the vision sensors from delivering their maximum performance. The laboratory was looking for compact speed reducers to resolve this problem.

Although HarmonicDrive® was appreciated for having no backlash, the required size was about the size of an adult index finger. The outside diameter of Size 5 was 20 mm, while that of an index finger was about 13 mm. It was too thick. As a result, HDSI decided to develop Size 3.

After a design revision, the thickness of the cup of the flexspline was 0.07 mm, and the gear height was 0.065 mm. Although there was no accurate means of measurement due to the unprecedented range of dimensions, HDSI completed a prototype (Figure 4) after repeated prototyping and testing while relying on the senses of the technicians.



Figure 4

Concurrently, Ishikawa Group Laboratory studied the motors and found that there was no compact, high-speed motor with sufficient power. As a result of considering motors suitable for Size 3, HDSI set development objectives for AC servo actuators with the world's smallest HarmonicDrive®.

HDSI started by designing a motor winding with high-

speed, high-torque specifications, and created a prototype by manual winding by an engineer. By installing an encoder with support from an affiliated company, HDSI completed the finger actuator.

As the next step, HDSI conducted study on the finger mechanism incorporating the actuator.

HDSI conducted structural design while doing a survey on patents related to finger mechanisms in the world. One of the major challenges was the joint mechanism for converting the rotary motion of the actuator output shaft to right-angled motion. Any backlash in the portion would negate the effects of using HarmonicDrive®. At the time, wire-driven joint mechanisms were commonly used, but these had problems in terms of stiffness due to wire elongation as well as size. HDSI proposed the bevel gear-driven mechanism based on an idea of a gear engineer. However, there were objections in the university because bevel gears generally required backlash and progressive wearing of the tooth flanks might cause backlash in the finger mechanism. As a result of comparison with the wire-driven mechanism, HDSI decided to adopt the bevel gear-driven mechanism based on the conclusion that it was better suited to satisfying the target external dimensions and high speed.

After devising a mechanism for eliminating backlash in bevel gears and adopting materials, heat treatment, and a special machining process for minimizing wear, HDSI completed one finger module.

As a result of testing, the module showed a faster response than expected. On October 8, 2002, the result was published at a press conference at the University of Tokyo as “Development of an Ultra-High-Speed Robot Hand.” HDSI named it the “UT/HDS hand,” and it has served as a basic structure used in university research over the years.

Furthermore, in response to demand from universities, HDSI developed a robotic hand up to the elbow joint by using other sizes of HarmonicDrive® actuators based on the wrist module with three fingers (Figure 5). It was used for research on motion control that was more precise than

human movements. As a result, HDSI expanded research relationships with researchers of other universities in the robotic hand fields.



Figure 5

Later, HDSI integrated this actuator into the standard mechatronics products as RSF-3 in 2006. The RSF-3 was awarded the Organization for Small & Medium Enterprises and Regional Innovation Award of the Robot Award 2007.

This series of efforts did not contribute greatly to sales in terms of business, but it did contribute to the expansion of applications. For example, a German equipment manufacturer that looked at the exhibit of this hand at a Japanese exhibition developed a hand system and ended up placing orders for special actuators.

A ball-catching system consisting of HDSI's hand and the vision system of the University of Tokyo, along with HarmonicDrive® components and explanation of its principle, had been on permanent exhibition at the National Museum of Emerging Science and Innovation for five years from 2007.

Because Size 3 was too small for customers to build in as a component, HDSI standardized Size 3 as the unit type with the casing and the flexspline integrated with the output shaft in 2006 (Figure 6).

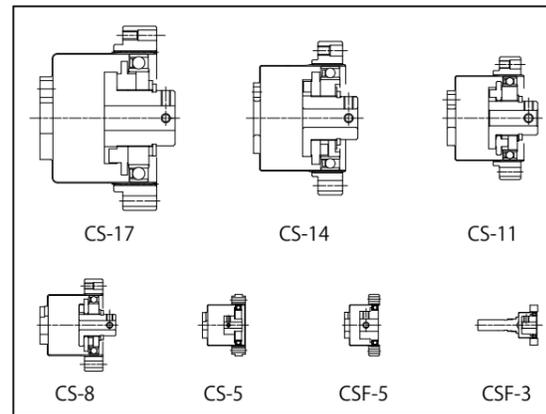


Figure 6 Standard series of compact components

## 2-1-4 Development of Special-Purpose Units

### Beginning of Development

As described earlier, most of the applications after the start of domestic production were specially designed units as requested by customers. The table below lists some examples, characteristics of HarmonicDrive®, and target technologies. The situation continued until the mid-1970s.

Symbol

HD: HarmonicDrive®

WG: Wave generator

CS: Circular spline

FS: Flexspline

Developed Products/Parts Applications	Main Characteristics of HarmonicDrive® Utilized
Double eccentric-type WG	Reduced moment of inertia and high-speed response of WG
Machine tools	
Triple eccentric-type WG	Higher load torque compared to double eccentric-type WG
Machine tools	
Dual roller-type WG	
Low-cost general-purpose applications	Low-cost WG
Sliding bearing-type WG	
Dedicated components for low-speed rotation (manual input)	Irreversibility, high load capacity, and low-speed input of HD
Heavy-weight shutter actuator	
Opening and closing of shutters of large buildings and warehouses	Compactness and light weight, high torque to weight ratio, high torque to volume ratio

Developed Products/Parts Applications	Main Characteristics of HarmonicDrive® Utilized
Lightweight shutter actuator (Figure 7)	Compactness and light weight, high torque to weight ratio, high torque to volume ratio
Opening and closing of shutters of residential garages and stores	
Manual valve actuator, WG sliding bearing type	Coaxial input and output, low-speed input rotation (manual input), high torque irreversibility
Opening and closing of butterfly valves	
Component using short-body FS	Compactness and light weight, high torque, coaxial input and output, easy mounting to devices
Power tools for tightening bolts	
Antenna actuator, planetary roller-type WG	High reduction ratios, compactness and light weight, reduction ratio of about 1/10 at WG
Adjustment of UHF TV antennas	
Knob unit for microscopes	Coarse and fine adjustment mechanism structure allowing for easy and compact mounting, coaxial input and output
Manual focusing of optical microscopes	
Torque controller (Figure 8)	Simple structure of torque detection mechanism utilizing HD's structure with three basic components
Overload protection devices, bolt tightening tools, and hopper gates	
HARMONIC MOTOR® for clarifiers, torque limiter	High reduction ratios allowing for 24-hour continuous rotation at ultra-low speed
Stirring of sewage in sewage treatment tanks of sewage plants	
Component for local float level indicators	Reversible rotation, high efficiency, easy setting of backlash according to application
Measurement of oil levels of oil tankers	
Sealed-type HD	Fully sealed structure, structure allowing for power transmission across the partition from input to output
Ultra-high-vacuum rotational motion feedthrough	
Winch with built-in HD	Compactness, easy mounting inside the drum
Hoisting machines for large and heavy objects	
Small hoisting machine	Compactness and light weight, easy mounting inside the hoisting machine, simple structure with CS output rotation
Portable-type hoisting machines	
Blind actuator	Compactness and light weight, high reduction ratios, thin actuator structure available
Electrical opening and closing of household blinds	

Developed Products/Parts Applications	Main Characteristics of HarmonicDrive® Utilized
Unit with medical traction motor	Speed multiplication, high efficiency, low noise
Whiplash treatment devices, spinal and lumbar traction	
FineJuster®	Flat type mechanism, easy mounting between adjustment shafts, easy phase adjustment
Power recirculation test equipment, printing machines, couplings	
Hydraulic motor unit	Hydraulic motor mounted in the FS interior space allowing for a small hydraulic unit
Compact high-torque actuator	
Kopp Harmonic	Combination of a speed reducer with a high reduction ratio and variable-speed drive
Variable-speed reducer market for HarmonicMotor	



Figure 7 Lightweight shutter actuator

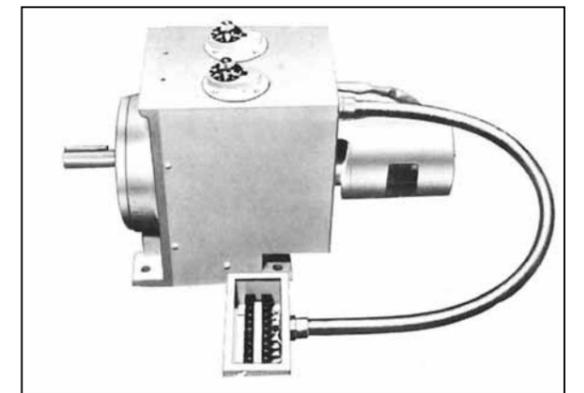


Figure 8 Torque controller

### Other Highlights

One example of technology that resulted from basic improvements based on these specification units and is still used as a basic component is the Oldham-type wave generator.

## 2-1-5 Development of the R Series for Robots (Size Nos. 20 to 100)

### Beginning of Development

Adoption for industrial electrically driven robots started with the use of about 10 units annually by Kleinwächter in Germany in 1971 and prototyping by KUKA in 1972. Adoption for full-scale mass-production robots started with ASEA in Sweden in 1973 and Renault in France. After that, in the 1980s, industrial robots became one of the major markets of HarmonicDrive®.

What contributed to the adoption of HarmonicDrive® for the joints of industrial robots in Europe was that Harmonic Drive System GmbH had been promoting and actively donating products to universities and companies since the 1970s.

Initially, HDSI supplied the BL series for robots.

However, the catalog of HarmonicDrive® at the time did not include specifications for industrial robot applications. The catalog listed the rated torque and input horsepower for each motor speed as in three-phase induction motors, and service factors for predicted degrees of shock, targeting the general industrial power transmission market.

Robot manufacturers would select the size of HarmonicDrive® based on the catalog specifications. This later led to many cases of damage of HarmonicDrive®. The joints of a robot constantly move back and forth and bear an impact load when starting and stopping. Partially because the applications in robots were at an early stage, loads exceeding the specifications were applied to HarmonicDrive®, causing damage of the Flexspline or jumping of teeth (called ratcheting).

There was strong demand from robot manufacturers to improve torsional stiffness and reduce vibration at the end of robot arms.

HDSI worked on the development of HarmonicDrive® for robots to resolve these problems.

### Technology Overview

HDSI introduced the early R series for robot applications

to the market in 1977 after improving machining accuracy and reducing backlash based on complaints analysis and discussions with robot manufacturers. The rating table was the same as before, but the specifications of allowable peak torque at start and stop were changed to suit the robot applications using servo motors as power sources (specifications fixed for robot applications in 1982). In terms of performance, HDSI standardized vibration testing simulating a robot arm, and established in-house standards. When establishing the in-house standards, HDSI gained the cooperation of robot manufacturers in taking correlations with the performance of actual robots.

Although vibration in robots was reduced due to improved performance of the R series, it was not sufficient due to the remaining problems of low shock resistance, low torsional stiffness, and damage of the diaphragm.

There were two types of damage of the diaphragm, one of which resulted from the oil holes on the diaphragm. The standard product since the technology introduction used oil lubrication, and there were six oil holes on the diaphragm for circulating lubricant oil. There were cases of damage starting from the oil holes. In 1980, Mr. Back, an engineer at ASEA, suggested applying the theory of stress concentration of the Royal Swedish Academy of Sciences for quantification. HDSI did an analysis, and decided to eliminate the holes in 1981. The oil circulation function was kept for the design of oil paths for other components.

The other type of damage was caused by stress concentration at the diaphragm and boss. Excessive load caused by collisions of the robot, insufficient stiffness and precision due to the weight reduction of the robot-side housing where the components were contained, and tilting of the output shaft caused by output bearing clearance resulted in excessive stress.

HDSI adopted the streamline fillet profile with a shape for reducing stress concentration of the diaphragm based on FEM analyses. In 1986, HDSI adopted it for all the standard cup-type flexsplines including the R series to resolve the problems.

In the same period, the problems of HarmonicDrive® and phenomena occurring in robots gave rise to competitors' development objectives for speed reducers. In 1986, competing RV speed reducers became available. As a result, HDSI lost market share for many of the large sizes.

HDSI kept getting closer to perfecting the R series for robots while learning from robot manufacturers in Japan and in European countries.

### Product Lineup

One of the challenges faced by robot manufacturers in selecting HarmonicDrive® was the high inertia of the wave generator. Accordingly, HDSI standardized the GR series with 30% less inertia in 1985.

## 2-1-6 Development of the High-Strength S Series

### Beginning of Development

Around 1985, HDSI had an opportunity to look at the result of a Delphi survey (the third survey in 1982; an expert survey on science and technology foresight) for predicting the development of science and technology in the 21st century. The survey predicted that the performance of actuators was expected to increase almost 10-fold in the 21st century. Accordingly, several engineers had a short discussion about the achievable level of performance of HarmonicDrive® after 10 years. They listed items and values out of the air, such as materials, design, stress concentration, and heat treatment, and made a general prediction. They saw some possibility of increasing the power transmission capacity 10-fold.

HDSI called it "Super HarmonicDrive® (SHD)" and undertook research by launching a project.

### Technology Overview

The project conducted repeated testing and numerical calculations. After a durability test, they observed the fractured surface, and measured the surface conditions of the wear surface and the shape of wear. Shoichi Ishikawa created mathematical formulas and expanded them into theoretical formulas.

During the process, Shoichi Ishikawa devised a method for making a large number of teeth mesh simultaneously based on the analysis of the shape of worn teeth and the movement trajectory of the teeth. This resulted in a tooth profile with a meshing zone three times greater from the major axis to the minor axis, which significantly improved the load capacity and stiffness of HarmonicDrive® (Figure 9).

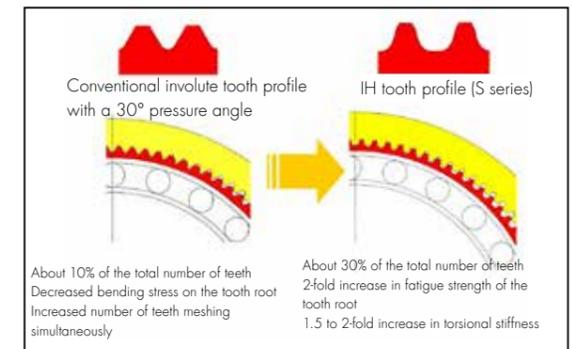


Figure 9

This tooth profile was initially called the S tooth profile because of its S shape. Later, it was called the IH (Ishikawa Harmonic) tooth profile. HDSI filed a patent in 1986, which was registered in 1995.

Completion of the special grease for HarmonicDrive® greatly contributed to the devising of the IH tooth profile. The grease suppressed the progression of abnormal tooth wear during durability testing, allowing the progression of normal wear to be measured (visualized), which led to the analyses and mathematical formulas. The grease is described later in "Other Highlights."

In 1988, HDSI introduced the CSS series with torque capacity and stiffness almost twice that of the R series to the market as HarmonicDrive® with the IH tooth profile (Figure 10). The series name comes from "CS (cup-type) S tooth profile series." Despite the increased torque capacity and stiffness, migration from the previous series in robot applications did not proceed as expected, possibly because the appearance and dimensions remained the same, making it less impressive.

On a side note, up to the R series, HDSI used the design calculation formulas established by USM. As a

result of using the IH tooth profile, HDSI created formulas appropriate for the IH tooth profile because the existing formulas became inapplicable. HDSI still uses the formulas created back then.

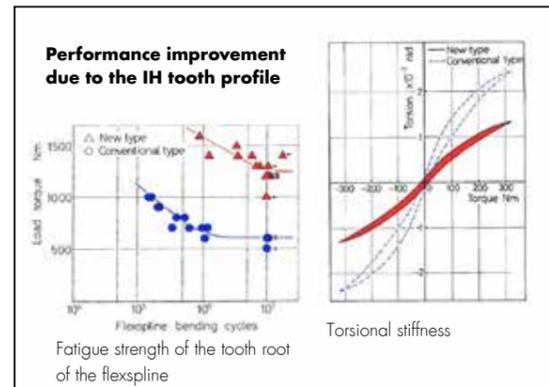


Figure 10

### Commercial Applications

The series was adopted for a wide variety of applications, such as industrial robots and semiconductor manufacturing equipment.

### Other Highlights

From April 24 to 27 in 1989, the American Society of Mechanical Engineers (ASME) held the 5th International Power Transmission and Gearing Conference in Chicago, where HDSI gave a presentation titled “HarmonicDrive® with the IH Tooth Profile.” Yoshihide Kiyosawa, manager of the Development Division at the time, described the background to the development of the new tooth profile and its theory, and explained the superior performance of the IH tooth profile by showing test data to compare it with the conventional HarmonicDrive®. During the Q&A session after the presentation, users and gear researchers asked many questions related to the gear theory and performance, demonstrating the high level of interest of the attendees.

As described earlier, the special grease for HarmonicDrive® greatly contributed to the realization of the IH tooth profile.

It might be worth mentioning the history of development of grease.

Since 1965, oil lubrication was used for Harmonic-

Drive® as standard. Grease lubrication was also used, but it had a short time rating (10 minutes, %ED of 10%). Greases and oils were selected from commercially available products.

Since the early 1970s, there was increasing demand for grease lubrication because of easier maintenance compared to oil lubrication. In particular, most robot applications used grease lubrication.

As grease lubrication required a longer life, expanded operating temperature range, and leakage prevention, HDSI evaluated dozens of commercially available greases on actual units. However, HDSI could not find an appropriate grease that satisfied the life, temperature characteristics, and leakage prevention requirements simultaneously. As a result, HDSI decided to develop a special grease in 1974.

Based on the experience and data accumulated through the evaluation of many commercially available greases, HDSI assumed that joint research with a manufacturer specialized in grease would enable development to be completed without taking a long time. However, these characteristics were mutually contradictory. Unable to find any correlation between the test data based on the standard grease evaluation criteria and the result of durability testing on actual HarmonicDrive® units, HDSI spent eight years conducting long hours of evaluation on actual units.

As a result, HDSI completed SK-1 and SK-2 (SK comes from the initials of the two developers) in 1982. This grease allowed HDSI to meet the demand for extended maintenance intervals of robots and contributed to the realization of the IH tooth profile. HDSI continued research on grease to expand the operating temperature range, and developed HC-1 with improved low-temperature characteristics in 1988.

In 1997, HDSI completed the 4B-No.2 grease for the thin cup type described later. At the same time, HDSI decided to discontinue HC-1 because the characteristics of 4B-No.2 were better.

As a result of continuing research on lubrication,

HDSI completed the HFL-1 grease for the food industry in 2018 in response to market demand, contributing to the expansion of applications of HarmonicDrive®.

## 2-1-7 Development of the Thin CSF Series

### Beginning of Development

Although the CSS series was improved in terms of strength and stiffness as a result of adoption of the IH tooth profile, it did not become as popular as expected as described earlier. On another front, HDSI decided to try to shorten the body of the flexspline because it was longer in the axial direction compared to competing products such as RV speed reducers and cycloidal speed reducers.

### Technology Overview

The technologies and products of HarmonicDrive®, whose domestic production started in 1965, were based on the technologies built on the large amounts of capital invested by USM and the efforts of many engineers.

As USM’s standard for HarmonicDrive®, design specifications and the range of allowable deviation from the basic dimensions were clearly defined in the manuals, which were usually followed during technical investigations.

One of such restrictions was the shortening of the length of the flexspline (i.e., shortening of the body). The outside diameter and length of HarmonicDrive® standardized by USM were beautifully balanced. According to the standard, these balanced dimensions should normally be used. However, there was a case of a special-purpose application that deviated from the standard, which was a component for bolt runners in 1975. This case involved shortening of the body by 20% by applying the restricted calculation formulas where the strength levels for the special purpose were confirmed through testing. It was the only successful case of shortening of the body over a period of 25 years until 1990.

Around 1990, while the CSS series did not become as popular as expected, HDSI decided to work on research

and development of shortening of the body as a standard series.

With accumulated technologies in FEM analyses and computer simulation, HDSI established the short-body flexspline technology in 1992, and introduced the first standard product to the market as the CSF series. The letter F comes from “flat.”

### Commercial Applications

The series was adopted for industrial robots as well as humanoid robots, which were becoming popular. It became popular more quickly than the S series.

### Product Lineup

HDSI worked on research to further improve the strength of the CSF series. In 2000, HDSI developed the CSG series with a 30% higher torque capacity by changing the material strength and tooth profile. The 4B-No.2 grease contributed to its commercialization.

By expanding the technology for shortening of the body into the compact series, HDSI introduced the CSF supermini series (Size Nos. 5 to 14) and CSF mini unit series (Size Nos. 8 to 14) to the market.

The technology for shortening the length of the flexspline established in 1992, along with the IH tooth profile, has been significantly contributing to the development of HarmonicDrive® as precision speed reducers.

## 2-1-8 Development of the Ultra-Thin CSD Series

### Beginning of Development

As the recognition in small robots increased, HDSI decided to try to develop ultra-thin cup-type HarmonicDrive® as thin as the pancake type (2-1-10) while having the characteristics of the cup type. The underlying motivation was to develop new applications other than robots.

### Technology Overview

HDSI started with a prototype, which did not rotate at all, but finally managed to complete it as a result of prototyping, feeding test results back into design, and technical analyses. HDSI achieved a length of a third that of the

CSS and half that of the CSF. While the power transmission capability decreased slightly due to the shorter length, HDSI achieved 70% that of the CSF, and created the CSD series in 2001 (Figure 11).

The letter D of the series name comes from “dish,” meaning it was as thin as a dish. HDSI selected this name because it was as thin as the pancake FB type while having the characteristics of the cup type.

HDSI has registered the design of the CSD to protect it.



Figure 11 CSS → CSF → CSD

### Commercial Applications

Although HDSI developed the series to develop new applications, it ended up being used for robots. In the U.S., the series was used for medical surgical robots.

## 2-1-9 Development of the Silk Hat Type SH Series

### Beginning of Development

Because the input and output shafts of HarmonicDrive® were coaxial, a hollow structure from the input shaft to the output shaft could be achieved by taking advantage of its structure, which had been achieved in the cup type. However, the hollow-shaft diameter was limited because the diaphragm was on the internal diameter side of the flexspline body. There were some attempts to mount other mechanisms such as a motor and brake inside the cup to utilize the space, but doing so was difficult.

Based on conversations with customers’ engineers, HDSI felt that widening the diaphragm of the cup of HarmonicDrive® outwardly would make the space inside the flexspline easier to use, which would expand its applications.

Similar units were shown in the materials of USM, but

USM did not recommend commercializing them because of high stress concentration.

Nonetheless, HDSI proceeded with the development thinking that it would help cultivate new demand.

### Technology Overview

Initially, HDSI created a prototype by welding a thin ring diaphragm on the outside diameter of the body, as in the flexspline of the cup-type CS-2 with a welded construction, because of the ease of manufacturing. As a result of testing, HDSI abandoned welded construction because the unit broke after a short period of time.

Later, HDSI became capable of manufacturing an alloy steel flexspline whose body and diaphragm were integrated after introducing NC lathes. After utilizing the analysis techniques that HDSI had been accumulating for the cup type and conducting testing repeatedly, HDSI introduced the SH series to the market in 1986. The series name SH is an acronym for “silk hat” because of its shape.

### Commercial Applications

The series was mainly adopted for robots. It has grown into one of the flagship products like the cup type because its structure allowed for a large hollow-shaft diameter from the input shaft to the output shaft and made the space inside the flexspline easy to use.

### Product Lineup

HDSI initially adopted the involute tooth profile as in the cup type at the time of technology introduction. After completing the IH tooth profile shortly after, HDSI introduced SHS with the IH tooth profile to the market in 1988, and SHF with a shorter body in 1995. Also, HDSI developed the super-flat SHD in 2003. HDSI achieved this by expanding and applying the technologies that HDSI had been accumulating for the cup type to the SH type.

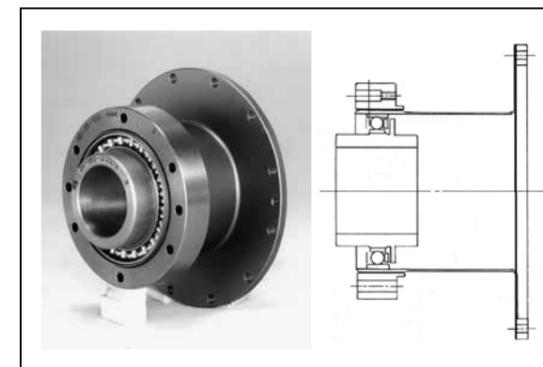


Figure 12 SH type

## 2-1-10 Development of the Pancake Type (Flat Type) (FB, FR, FD, FH, Differential, and J)



Figure 13 Pancake-type speed reducer

The pancake-type speed reducer shown in Figure 13 was a catalog product of USM, which Hasegawa Gear Works listed in the catalog, but for which there was no record of sales.

The pancake type was a special type of HarmonicDrive® with a dynamic spline. The dynamic spline, like common splines, is a coupling used to couple the shafts to transfer the same rotation speed and torque. One of the differences from the common splines is that it has dynamic characteristics. It consists of a flexspline and circular spline that have the same number of teeth. Instead of all the teeth meshing simultaneously, only the teeth across the major axis of the flexspline, which is deformed to form an ellipse, mesh with the teeth of the circular spline to transfer torque. The teeth meshing position gradually moves in a circumferential direction as the ellipse moves. The dynamic spline can be used to shorten the length in the axial direction because the body of the

cup type becomes unnecessary, allowing for a compact HarmonicDrive® mechanism with high torque and high stiffness.

Apparently, USM called it the pancake type because it is as “flat as a pancake” when compared to the cup type.

Later, HDSI called the thin HarmonicDrive® with a short cylindrical flexspline (about the length of two circular splines) the flat type and expanded the product lineup.

### Beginning of Development

At the beginning of 1970, with no ongoing applications, HDSI decided to create a low-cost HarmonicDrive® to develop new applications and secure sufficient orders. HDSI aimed at the pancake type.

The pancake type of USM used two wave generator bearings for the two circular splines.

To reduce the price of the pancake type under development, HDSI decided to use only one wave generator bearing, calling it the “single-wave pancake Harmonic Drive” at the time.

Having the center of the balls of the wave generator bearing in the middle of the two circular splines, the design seemed normally unachievable because of how load was applied to the bearing and uneven load on the gear meshing. Therefore, HDSI started with demonstration testing to see if it was practical.

### Technology Overview

The objectives included 30% cost reduction compared to the cup-type component and restriction of use in short-term intermittent operation at the rated torque, with the same allowable torque and input rotating speed as the cup type.

The stress in the gear meshing of the dynamic spline, which was one of the concerns, was distributed due to the effect of the shifted HarmonicDrive® (patented by Shoichi Ishikawa). Practical levels of wear resistance and fatigue limit were ensured.

In 1972, HDSI introduced FB-20, 25, and 32 to the market as the FB series, and continued expanding the series (Figure 14).

In the series name, the letter F came from “Flat,” and

the letter B came from “ball bearing.” HDSI marketed it as the pancake type HarmonicDrive®.

### Commercial Applications

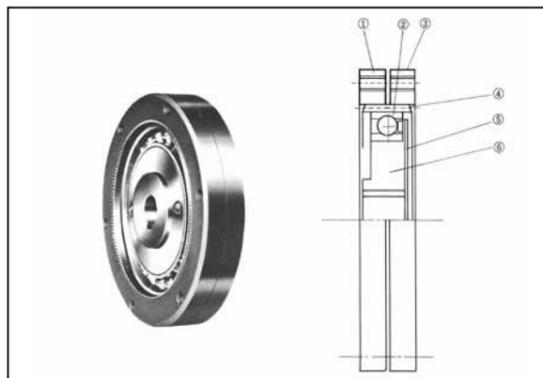


Figure 14 FB type

The series had no notable applications because of some problems, such as high lost motion compared to the cup type. However, its product life has been maintained after repeated improvements because of a wide variety of applications although small in volume.

### Product Lineup

#### ■ FD type

Concurrently with the FB type, HDSI developed the phase adjustment differential unit FD type.

For phase adjustment of a printing machine, some European printing machine manufacturers used a phase adjustment unit combining the cup type and spur gears, or a differential unit using two cup-type HarmonicDrive® units with their flexsplines connected back to back (Figure 15). In this application, HarmonicDrive® was used as a phase adjustment or timing adjustment unit rather than a speed reducer. The reason for using two HarmonicDrive® units was that placing speed reducers in line made the unit more space-saving and less noisy compared to other gear train units.

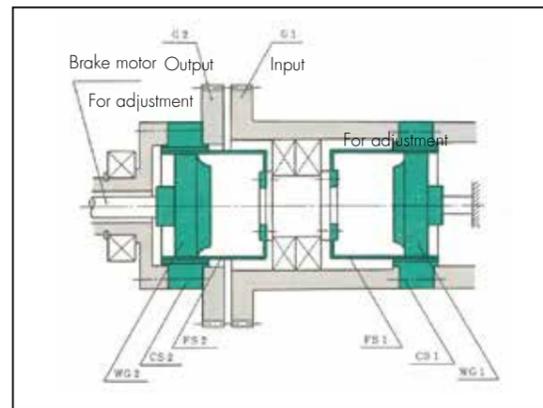


Figure 15

During that period, a mid-sized printer manufacturer in Germany made the suggestion of creating a differential gear for phase adjustment of the drums of printing machines.

The structure consisted of the pancake-type component of USM with a total of four built-in bearings, two support bearings between the wave generator and the circular spline, and two support bearings between the casing integrated with the circular spline and the user-side adjustment shaft, making the unit easy to mount to the mechanical equipment (Figure 16).

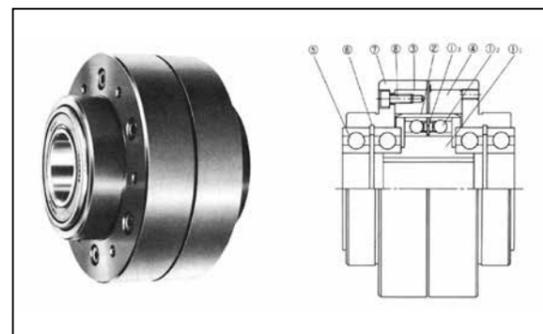


Figure 16 FD type

Harmonic Drive System GmbH acquired the suggestion and envisioned its standardization.

In Japan, HDSI commercialized the phase adjustment differential unit FD type in 1972. As in the case of the FB type, the commercialization took advantage of the technology of the shifted HarmonicDrive®.

In the mid-1970s, the FD type replaced the cup type in the six-color printing process for plastic sheets and plastic

bags, and its applications started to expand (Figure 17).

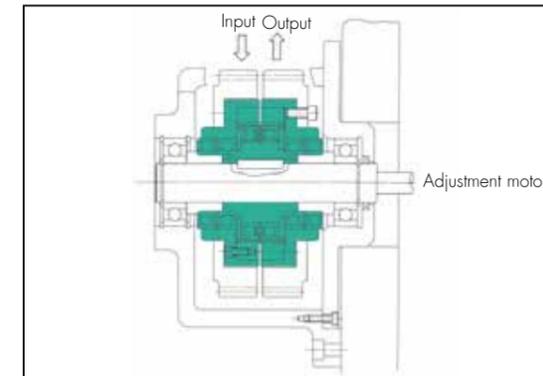


Figure 17

This led to a wide variety of applications, including centrifuges, brake testers, torque limiters, roller adjustment of carpet handling equipment, and grindstone grinding machines.

#### ■ FR type

HDSI standardized the HarmonicDrive® built into the differential type as a thin speed reducer with the same torque capacity as the cup type, and introduced the flat-type-component FR series to the market in 1979 (Figure 18).

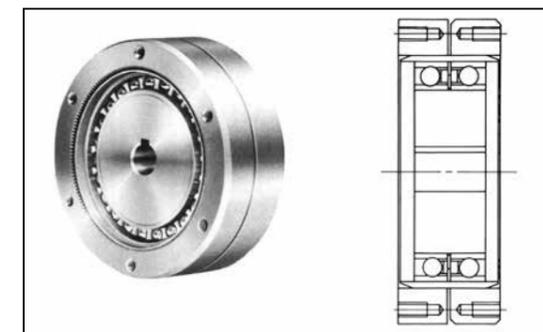


Figure 18 FR type

#### ■ FH type

In addition, HDSI introduced the component portion of the valve actuator commercialized for special-purpose applications as the FH2 type (for manual low-speed input rotation) to the market in 1972 (Figure 19). HDSI used a sliding bearing instead of a rolling bearing for the wave generator, and created the series with Size Nos. 20, 25,

and 32. The maximum allowable input rotating speed was 40 r/min.

Although HDSI received inquiries about applications in automobile seat adjusters, none of them was adopted.

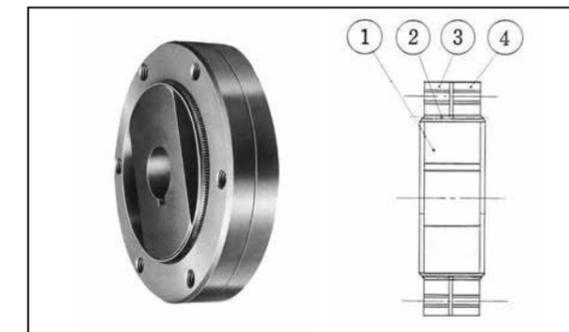


Figure 19 FH type

#### ■ Dual type

The dual type allowed for ultra-high reduction ratios and ultra-low reduction ratios with a single stage by using different reduction ratios (R1 and R2 in Figure 20) for the speed reducer-side circular spline and the rotation output-side circular spline of the FR type. It was also described in *ILLUSTRATED APPLICATIONS* of USM.

Although no dynamic spline was involved, HDSI categorized it as the pancake type because it had a thin structure. HDSI once prototyped the ultra-high reduction ratio type for solar tracking systems, but did not put it to practical use because the output rotation was not smooth and the efficiency was low.

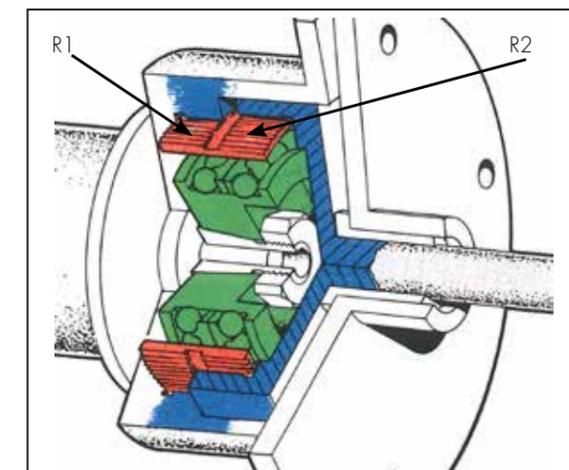


Figure 20 Excerpt from *ILLUSTRATED APPLICATIONS*

## Other Highlights

The dual type was first put to practical use in the VCT (variable-compression turbo engine) of Nissan Motor Co., Ltd. It was adopted in 2016. The system achieved the variable compression ratio by moving links, and the dual type was used for the actuating mechanism.

As the explosive force of the engine was directly applied to this mechanism, a common gear with backlash would be damaged in a short period of time. Among the various speed reducers that could operate with low noise in dirty engine oil at high temperature being tested, the CSD type achieved the required functionality.

As a result of joint development with HDSI, Nissan Motor adopted the dual type due to high reduction ratios and efficiency that was not too high.

## 2-1-11 Development of the Unit Type

### Beginning of Development

The beginning of development of the unit type for robots was the four prototypes exhibited at an exhibition in 1984. As the cross roller bearing (CRB) for the output bearing, a commercially available general-purpose product was adopted. The development was planned and started by the Marketing and Development Departments, but was halted half way through according to the company's decision that it would not sell because of its price that was twice that of the component and the lack of vibration control.

By the late 1980s, HarmonicDrive® components had built a strong track record as speed reducers for industrial robots, despite the problems of vibration, etc. Around that period, robot manufacturers tended to focus on the software aspect by leaving the hardware aspect to specialized manufacturers. In fact, HDSI delivered specially shaped units in response to demand from multiple robot manufacturers. In addition, competing products such as RV speed reducers and cycloidal speed reducers had a unit shape.

Against this background, HDSI launched the standard unit development project in 1989 to further reduce the weight of the units meeting special requirements, aiming at easy mounting, low price, and use of common parts. As HarmonicDrive®, Size Nos. 20 to 50 of the CSS type and Size Nos. 14 to 50 of the FRS type were to be used. The performance was basically to be equivalent to that of the S series component.

The reason for adopting the CSS and FRS types simultaneously was to provide robot manufacturers with more options for different portions, such as the wrist and the body, of two different types of robots, vertically articulated and horizontally articulated, so that HDSI's components could be adopted for all the axes of small robots.

In 1991, HDSI developed the unit type with the CSS component, and introduced it to the market as the UX series targeting easier mounting and lower total cost (Figure 21).



Figure 21 UX series

### Product Lineup

In 1992, HDSI introduced the more compact CSF-2UH with the CSF-type component to the market (Figure 22).



Figure 22 2UH series

In 1995, HDSI introduced SHF-2UH to the market followed by the CSG and SHD units.

The weight reduction was only about 15% of the respective weight, but they gradually became popular due to demand for weight reduction.

2-1-15 summarizes the development of the component type and expansion into the unit type.

HDSI had been marketing HarmonicDrive® units as speed reducers for precision control with selling points of light weight and compactness. As the units became structurally compact, their weight became not much different from that of competing speed reducers. Aiming at further weight reduction with a minimum decrease in performance and the same shape, HDSI introduced the LW series to the market in 2012 by adopting lightweight materials and a structure designed with lightening holes while maintaining stiffness. The series name came from "Light Weight."

Aiming at further weight reduction, HDSI introduced the unit-type ULW (ultra-light weight) series that was 30 to 50% lighter to the market in 2020 (Figure 23).

HDSI achieved unprecedented light weight and flatness by refurbishing the structure and design of CSF-2UH, which was the flagship product of the unit type.



Figure 23 ULW series

### Development of CRB

As the output shaft-side bearing of the HarmonicDrive® components used for robot joints since the 1970s, two rows of deep-groove ball bearings or an angular contact bearing was mainly used. CRB gradually started to be used to reduce the size of joints. HDSI launched the UX series with a special-specification CRB as the output-side main bearing, which was supplied by a specialized manufacturer. However, the special-specification CRB failed to deliver performance equivalent to that of the component type due to the clearance adjustment in the rolling contact area and moment stiffness, leading to the necessity to develop a CRB in-house.

### Technology Overview

The development objectives for the CRB included low-speed rotation because it was dedicated for the output shaft of speed reducers, and a preload with zero clearance in the rolling contact area. HDSI started development in 1992 by applying the grinding technology that HDSI had been accumulating for other purposes.

With no design technology or manufacturing technology for CRBs at the time, HDSI disassembled a commercially available CRB, measured its dimensions, and made technical drawings. As a first step, HDSI created a prototype by assembling parts with exactly the same dimensions. Engineers and technicians together checked the clearance and stick-slip based on tactile sense by manually turning the prototype. After repeated design modifications and prototyping, they reflected the results in dimensional changes of the inner and outer rings, angular

adjustment, and selection and combination of rollers.

At the same time, HDSI manufactured evaluation equipment for the moment stiffness and characteristics of CRBs, and acquired manufacturing technology for the proprietary low-speed CRB. In 1995, after performance evaluation and durability testing, HDSI adopted the CRB for the unit-type products, including all the unit series.

The unit type with this new CRB could be mounted to joints more easily than the component type. As the added value of robots shifted to systemization, flagship products have been gradually changing from the component type to the unit type until now.

### ■ Development of XCB

Meanwhile, in the CSF supermini series, a compact, thin output shaft support bearing was required to take advantage of the component with a shorter body. The conventional two rows of deep-groove ball bearings were long in the axial direction, making it impossible to take advantage of the shorter body of the flexspline of CSF. HDSI then considered adopting a CRB, but ended up adopting a four-point contact ball bearing because the CRB was difficult to assemble due to its small roller diameter. HDSI tried to develop it in-house because no bearing manufacturer would supply it. In 2002, HDSI completed the proprietary four-point contact ball bearing “XCB.”

To bear radial, thrust, moment loads with deep-groove ball bearings or angular bearings that were traditionally used for general purposes, two bearings had to be used in combination. In contrast, one XCB could bear the loads in all directions because each ball was in contact with the raceway grooves of the inner and outer rings at four points. It was suitable for the downsizing of the unit structure of the CSF supermini series. It was called “X Contact” because connecting the four contact points formed an X. HDSI called it “XCB” by abbreviating “X Contact Ball Bearing.”

The XCB has greatly contributed to the creation of product features along with the CRB described earlier.

### Commercial Applications

The products were adopted for industrial robots.

### Other Highlights

For the mass production of CRBs, HDSI established its own dedicated factory after in-house production, contract production by an affiliated company, and concurrent procurement from a manufacturer specialized in CRBs. While seeking to establish an efficient production method, HDSI established the CRB manufacturing company Harmonic Precision Inc. in July 1999.

## 2-1-12 Development of the Bent Sub (for Oil Drilling)

### Beginning of Development

As the main player in oil drilling changed from onshore oil drilling to offshore oil drilling, the drilling method of drilling into the ocean floor in all directions with drilling assemblies from platforms became mainstream. This was because it was difficult to have multiple drilling rigs as in onshore oil drilling due to the massive amounts of money required to build a platform.

At the time, the method for turning the oil well was to use a wedge called a whipstock.

This was done to let the drilling assembly deflect naturally along the strata. However, this method had to be used many times until the drilling assembly became horizontal, which required expert skill and enormous time.

Against this background, the Japan National Oil Corporation (disbanded in 2004) initiated a project to conduct research and development of an oil drilling rig using new technology. In 1990, Sumitomo Metal Industries, which was assigned the advancement of the project, and HDSI had a meeting at HDSI’s factory, at which Sumitomo Metal Industries sought advice on the development of a mechanism that could freely bend the tip of the rig.

### Technology Overview

HDSI suggested that such a mechanism could be built by using a combination of a large hollow HarmonicDrive® and eccentric disc. Despite the development cost, HDSI

started the development as the advantages of the mechanism were appreciated.

This mechanism was called the bent sub. The outside diameter of the bent sub was determined by the size of the hole. There was a pipe going through it for turning the bit. Various equipment required for accurate driving of the rig had to be housed inside the small doughnut-shaped space between the pipe and the outside diameter. Although it was difficult to achieve with conventional technology, HarmonicDrive® was a speed reducer with the optimal structure because it allowed for a large hollow space.

HDSI decided to combine the output rotation of

HarmonicDrive® with eccentric discs as the mechanism for changing the direction of the tip of the rig. This idea was based on the principle of using two eccentric discs to freely change the direction of the rig because an eccentric disc could be used to change the center position.

The project started in 1992. First, the idea of using the bit shaft as a driving source for the large hollow HarmonicDrive® and controlling it with an electromagnetic clutch brake started taking shape. This became the basic patent for the bent sub. Later, the project completed the final mechanism by adopting double eccentric discs.

The project of the Japan National Oil Corporation, which lasted for eight years in two terms, demonstrated

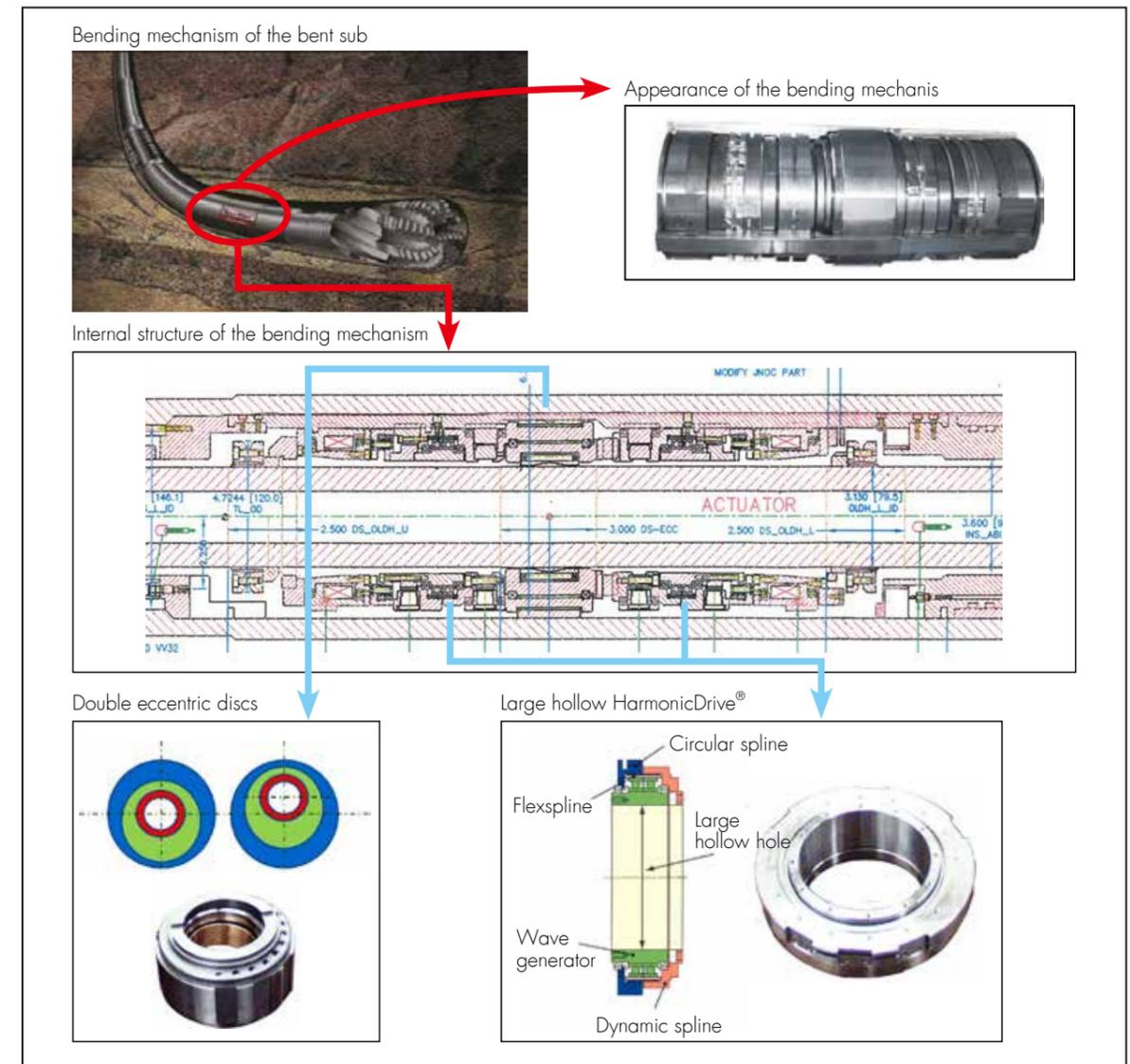


Figure 24

that the oil well could be bent. This technology was later put to practical use by Sperry-Sun Drilling Services, Inc. (SSDS, currently Halliburton Company), forming a big market.

This demonstrated that HarmonicDrive<sup>®</sup>, which was previously regarded as a precision speed reducer, could be used for severe civil engineering work at a temperature of 165°C, pressure of 1,200 bar, and constant shock and vibration of 25 G.

## 2-1-13 Development of the In-Vehicle Type

### Beginning of Development

There was demand for in-vehicle applications of compact and lightweight HarmonicDrive<sup>®</sup> in the early 1970s. These applications included air conditioner louvers, power steering, powered windows, seat adjusters, and windshield wipers, none of which took shape due to the demand for low prices.

Soon after the turn of the 21st century, HarmonicDrive<sup>®</sup> was adopted for variable-steering actuators.

### Technology Overview

Some of these applications previously used hydraulic systems or planetary gears. Variable gear ratio steering systems (VGRS) aimed at the electrification of such applications.

To improve the driving safety of cars, the system turned the vehicle sharply with a small steering wheel angle at low speed, but did not turn it sharply with a larger steering wheel angle at high speed. One of the manufacturers was pursuing research by using the cup type of HarmonicDrive<sup>®</sup> in the system. However, in the cup type, any damage to the bottom of the cup (diaphragm) of the flexspline would free up the wheel, making steering impossible. Therefore, power transmission had to be made possible in case of damage. In addition, the required torque was too high. HDSI decided to develop the dedicated pancake FB type.

As a result of satisfying the required specifications such

as light weight, compactness, quietness, high reliability, and ease of assembly, it was adopted in 2002.

The size was equivalent to Size 17. The series name was the VF (vehicle flat) type. The VF series for VGRS was later adopted for several vehicle models, leading to the first mass production of in-vehicle units. HDSI established dedicated lines for mass production.

### Product Lineup

After entering the in-vehicle equipment market with the VF series, HDSI developed the VC (vehicle cup) type for controlling electric stabilizers. At the time, the use of hydraulic power for stiffness control of stabilizers had been put to practical use. Manufacturers were aiming at electrification for finer control. HDSI received inquiries about HarmonicDrive<sup>®</sup> with high reduction ratios for generating high power with a small motor.

The requirements included small diameter, high torque, high reduction ratios, high shock resistance, and ease of assembly. HDSI met the targeted requirement values by using customized design. HDSI satisfied the requirements by adopting special machining methods. As a result, the VC type was adopted for electric stabilizers in 2005, which was expanded to several vehicle models.

Other in-vehicle applications included the VCT application in 2016 as described in the section on the pancake type.

All of these cases required technologies that HDSI had been accumulating for over 35 years since the start of domestic production of HarmonicDrive<sup>®</sup> as well as new technologies.

## 2-1-14 HarmonicDrive<sup>®</sup> for Space Applications

### Beginning of Development

The catalog of USM at the time of the technology introduction described HarmonicDrive<sup>®</sup> as being used for the wing drive mechanism of the Pegasus micrometeoroid detection satellite with photographs and illustrations. Hasegawa Gear Works attached this in the Japanese ver-

sion of the HarmonicDrive<sup>®</sup> catalog intended for domestic use. The Japanese version stated that HarmonicDrive<sup>®</sup> had been classified as critical components related to satellites and national defense by the United States Department of Defense and the National Aeronautics and Space Administration (NASA) but that USM had recently made HarmonicDrive<sup>®</sup> commercially available in the United States.

Initially, USM had a limited track record of selling HarmonicDrive<sup>®</sup>, and gave higher priority to aviation and space satellite equipment where its light weight and compactness had absolute advantages and had a track record since the 1960s.

However, at the time of the technology introduction, Hasegawa Gear Works did not consider the Japanese market as a promising market, and had no track record for 20 years after the start of domestic production.

Under such circumstances, HDSI received an order for the development of HarmonicDrive<sup>®</sup> for space applications from a Japanese electric appliance manufacturer in 1983, and started development after exchanging memorandums. The electric appliance manufacturer was commissioned by the National Space Development Agency of Japan (at the time; later merged into the Japan Aerospace Exploration Agency (JAXA)) to develop the system for driving solar paddles in a period of about five years. In preparation for the development, the electric appliance manufacturer spent about four years until 1982 to investigate case examples in foreign countries and future trends, and set target specifications. The manufacturer and HDSI jointly started prototyping and evaluation testing of the HarmonicDrive<sup>®</sup> CS-20-2A as the mechanism for driving the paddles.

In 1992, the Japan Earth Resources Satellite-1 with domestically produced HarmonicDrive<sup>®</sup> was launched. After that, HarmonicDrive<sup>®</sup> was used in various space equipment of the company.

In 1987, HDSI received an inquiry about HarmonicDrive<sup>®</sup> for Space from a space equipment manufacturer that developed space equipment with HarmonicDrive<sup>®</sup>

manufactured by USM and had a good track record in the United States, and started the development. In 1990, it was adopted for the joints of the arms (at 14 locations) and the postural maintenance legs (at 5 locations) of the Flight Telerobotic Servicer (FTS), and HDSI delivered 49 units in 1991.

The domestically produced units were adopted while HarmonicDrive<sup>®</sup> manufactured by USM had become the de facto standard for astronautic motion control units and actuators in the United States by the mid-1980s.

Around that time, HDSI also worked on developing technologies and establishing quality management aiming for the establishment of HarmonicDrive<sup>®</sup> for Space. In 1991, HDSI released it to Japan and overseas at the International Symposium hosted by HDSI. This result led to the customization of the high-strength CSS-type component, which was immediately after commercialization, and its application in the FTS.

### Technology Overview

Major technologies to be established involved selection of materials, weight reduction, understanding of the characteristics related to temperature change, and lubrication and life in a vacuum environment.

#### Materials:

Because space equipment required a long period of time from the completion of manufacturing on the ground and delivery to space, HDSI adopted stainless steel for its corrosion resistance during storage.

#### Weight reduction:

Space equipment needed to be as lightweight as possible in terms of fuel consumption during a launch. Although HarmonicDrive<sup>®</sup> was compact and lightweight for industrial applications, HDSI thoroughly used lightening holes in each component to make it lighter, resulting in weight reduction by 50 to 60% compared to the CSS type standard product. While components with lightening holes could easily deform and affect the characteristics of HarmonicDrive<sup>®</sup>, HDSI established techniques for precision machining of difficult-to-machine stainless steel materials.

### Understanding of the characteristics of HarmonicDrive® related to temperature change:

Based on the understanding of the characteristics in the temperature range of -20°C to +80°C, including stiffness, efficiency, running torque, starting torque, and overdrive starting torque, HDSI set the optimal clearance and interference for each part. HDSI reflected the result that these characteristics were proportional to the viscous resistance of the lubricant in the selection of lubricants.

### Lubrication in a vacuum environment:

HDSI ensured durability by defining the specifications of lubricants for a vacuum environment and applying vacuum pressure impregnation of the bearing cage with the lubricant.

### Quality control:

Because space components required rigorous quality control and traceability, tolerance management and strict recording of manufacturing history were required. HDSI established and complied with quality assurance systems for space components.

While accumulating these technologies, HDSI worked on putting customized components to practical use with much support from the customers, including lubricating treatment and durability assessment.

### Product Lineup

HDSI customized the flat cup-type CSF series that they had been developing as speed reducers for precision control, the super flat CSD series, and the silk hat-type SHF series that was commercialized by HDSI for the first time (see Figure 26) based on the operating conditions, which had an excellent record in various space equipment manufactured in Japan, the U.S., and Europe. HDSI has been continuing the efforts until now.

In 2008, SHF-20 and CSD-20 developed based on the development specifications of JAXA were registered as JAXA's component parts (Figure 25).



Figure 25 SHF-20 registered as JAXA's component part

### Special notes

As described in the company history, at the International Symposium hosted by HDSI, space equipment manufacturers of Japan, the U.S., and Europe, as well as public-sector organizations made presentations about the past, present, and future outlook of development related to space. The sharing of information with customers as well as HDSI's employees was extremely fruitful. HDSI will continue to host the International Symposium in the future.

## 2-1-15 History of HarmonicDrive®

As described in the preceding sections, HDSI has been continuously seeking to improve the strength and rotational accuracy of HarmonicDrive® from domestic production in 1965 to 2020.

One of the important indexes related to the strength of speed reducers is the torque-to-volume ratio. Figure 26 shows the result of seeking compactness and light weight, which are the major characteristics of HarmonicDrive®, in terms of shape.

During this period, the torque-to-volume ratio has increased three- to four-fold for the same size of HarmonicDrive®. HDSI achieved this by exploring detailed shapes and making innovations related to materials

through technical analyses. HDSI also achieved exponentially higher machining accuracy and improved the rotational accuracy about 10-fold.

The realization of high strength, i.e., compactness, and higher accuracy, evolved HarmonicDrive® from the initial power transmission applications to precision control applications, significantly contributing to market creation.

As described herein, HDSI also put to practical use Musser's various ideas about HarmonicDrive® shown in *ILLUSTRATED APPLICATIONS* which were not in practical use to meet the market demand.

HDSI has achieved this with an upward spiral of its technologies and skills. One of the missions of HDSI is to keep evolving HarmonicDrive® toward the future.

### Development of the Component Type and Expansion into the Unit Type

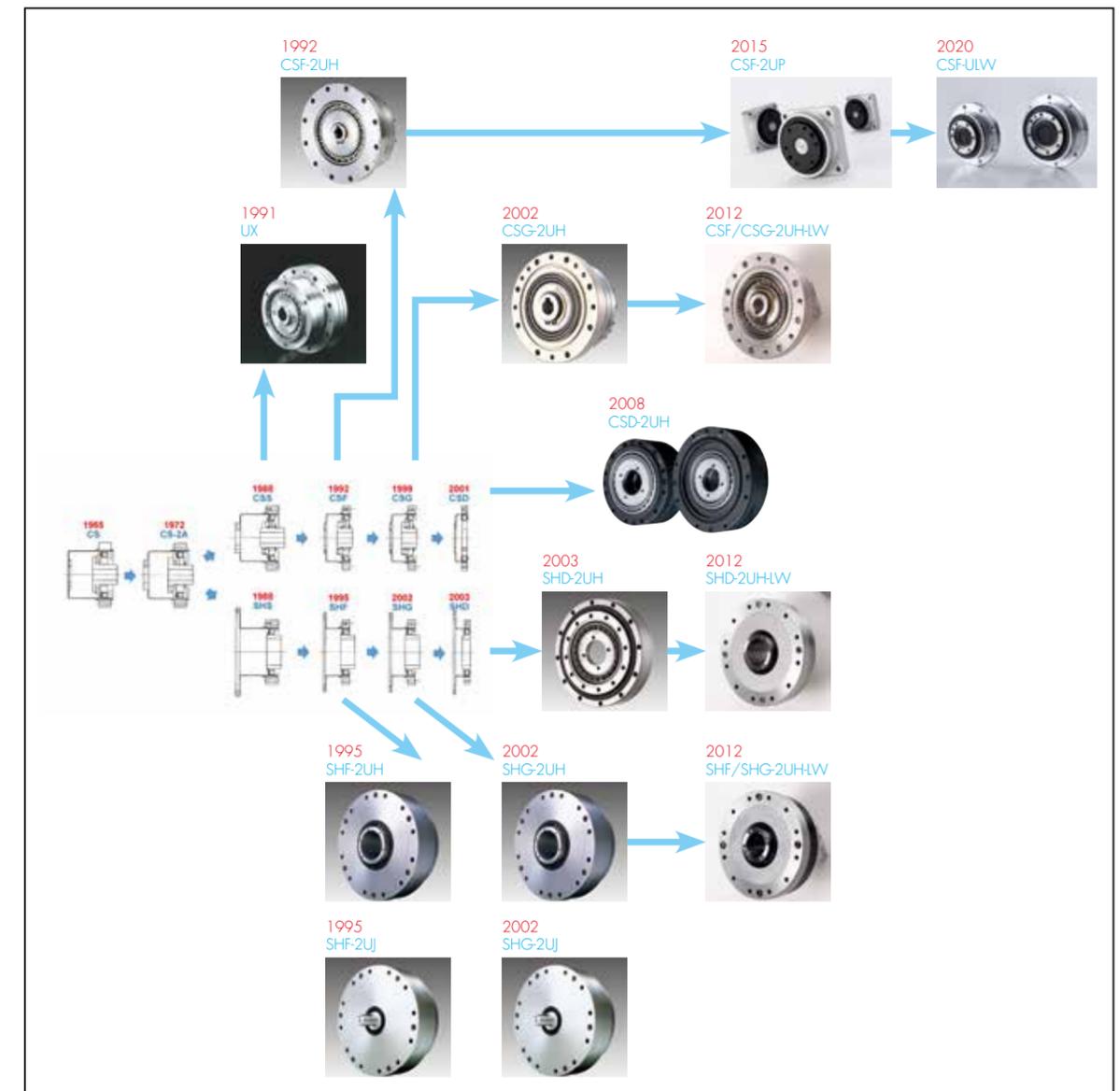


Figure 26

## 2. Mechatronics Products

### 2-2-1 Development of Servo Actuators

#### DC Servo Actuators

##### Background of Development

In the management policy of 1977, HDSI announced that it would expand its production, sales, and development activities into product areas other than HarmonicDrive® units in the future.

The intent was to identify HarmonicDrive® as the first pillar and seek the second pillar from a long-term perspective.

After over 12 years since its release in Japan, HarmonicDrive® was recognized to some extent as unique speed reducers in the market. However, it showed little growth due to the recession, and there was increasingly fierce price competition.

Based on this understanding, HDSI decided to develop servo actuators by positioning HarmonicDrive® as a power transmission mechanism for servo systems.

Accordingly, HDSI started commercialization with the development theme of the “harmonic servo motor” consisting of a DC servo motor and HarmonicDrive®, targeting completion in December 1977.

HDSI also decided to commercialize the “electro-hydraulic servo actuator” consisting of a hydraulic motor and HarmonicDrive®.

These two themes were set as the first step toward servo systems. Major applications included precision control fields including NC machine tools, special-purpose machines, and robots.

Among these themes, HDSI proceeded with the development of the “electro-hydraulic servo actuator” jointly with a hydraulic equipment manufacturer and servo motor manufacturer. However, many problems, in terms

of vibration, noise, and transmission torque, were found when the prototyping was completed. Concluding that these problems could not be resolved in a short period of time, HDSI abandoned the development.

#### ■ HT Series

HDSI commercialized the “harmonic servo motor” consisting of a DC servo motor and HarmonicDrive® as described above as “Hi.T Drive” in 1978.

At the same time, HDSI created the new Actuator Product Group (AP Group) with Hi.T Drive as its flagship product. In the business plan of fiscal 1978, the role of the group was defined as “serving as a comprehensive development project including product planning and development, market development and user acquisition, and research and ensuring of optimal sales method in order to nurture the actuator products as a new product pillar,” which marked the first step toward the later mechatronics business.

#### Technology Overview

HDSI decided to use DC servo motors, which were mainstream at the time, and procure them from outside sources along with encoders. HDSI developed actuators by combining them with HarmonicDrive® and called them “Hi.T Drive.” In 1978, HDSI created the HT-14, HT-20, and HT-25 series, and later introduced HT-8 to the market in 1982. “Hi.T” is derived from “high torque” (Figure 1).

The selling points were its performance at low speeds (superior rotational accuracy and positioning accuracy from the top speed of 80 r/min to the ultra-low-speed region), high output torque, light weight, and compactness, and an advantageous total cost (inexpensive control device due to low current input).

HDSI decided to sell drivers of other companies under the brand of HDSI as a control system, and started to develop the product lineup as a system.



Figure 1 HT series

#### Commercial Applications

The products were adopted for wafer transport systems of semiconductor manufacturing equipment, machine tools, special-purpose machines, gas welding/cutting apparatus, radars, testers, and winders.

#### Product Lineup

#### ■ RA Series

In 1984, HDSI commercialized the RA series (Robo-Drive) with a 50% shorter length in the axial direction than Hi.T Drive in response to market demand (Figure 2).

HDSI adopted the HarmonicDrive® R series. Later, HDSI kept adopting the latest series of HarmonicDrive® for subsequent actuators.

The HT series had the structure of a common speed reducer where the circular spline was fixed to the housing and the flexspline was used as the output.

For the RA series, HDSI devised a design where the flexspline was fixed and the circular spline was used as the output to significantly shorten the length in the axial direction. Also, HDSI adopted flange output rather than shaft output.

To shorten the total length of the speed reducer portion, HDSI placed the support bearings for the circular spline serving as the output on the outer periphery side of the flexspline so that they did not affect the length.

Furthermore, HDSI aimed to expand the lineup of easy-to-use actuators for robots by placing the case mounting flange of the actuator near the motor body and adopting a wall mount structure.

In addition to the shortened structure of the speed reducer portion, HDSI developed in-house the motor and encoder for the first time, which had been procured

from outside sources.

After that, HDSI started accumulating motor technology and encoder technology and selecting from parts developed in-house and parts procured from outside sources as needed.

After being introduced to the market, the RA series did not evolve because the structure of using the circular spline as the output had problems, i.e., 1) it was heavy for its size, and 2) it was difficult to handle in terms of control because the reduction ratios were indivisible for HarmonicDrive® with the same gear ratio as the HT series.



Figure 2 RA series

#### ■ RH Series

The RH series was a “Hi.T Drive” product with the motor and encoder developed in-house for the RA series. HDSI introduced the three sizes of RH-20, 25, and 32 to the market in 1984 as with the RA series (Figure 3).

The speed reducer portion used shaft output from the flexspline like the HT series. Although RH series didn't have a thin structure, it kept evolving as cylindrical actuators.

In 1987, HDSI introduced RH-5, 8, 11, and 14 to the market as the micro & supermini series.



Figure 3 RH series

#### ■ RK-J Series

As industrial robots became popular and robot manufacturers started to sell robots, robot users also started to develop their own unique robots to be used in-house. There were growing needs among these robot users for actuators for joints.

Against this background, HDSI commercialized the robot joint actuator module RK-J series (ROBOT MODULE) to the market in 1984 (Figure 4).

However, robot manufacturers started to sell robots at lower prices, leading fewer users to develop their own robots. Losing sales opportunities, HDSI discontinued the product.



Figure 4 RK-J series

#### ■ RF Series

In the RF series, shaft output of the RH series was changed to flange output to offer more options of output connection to robots. HDSI released it in 1989 (Figure 5).

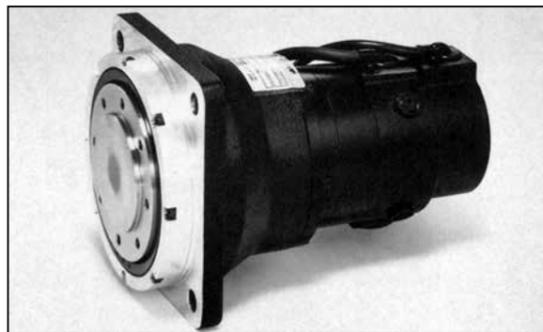


Figure 5 RF series

#### ■ RHS/RFS Series

The RHS and RFS series were improved versions of the RH series. HDSI developed the shaft output-type RHS in 1989 by combining the HarmonicDrive® S series commercialized in the same year and the DC servo motor developed in-house. After that, HDSI introduced the flange output-type RFS to the market in 1990.

Later, HDSI kept expanding the product lineup of the micro series and supermini series of DC servo actuators as it developed smaller HarmonicDrive® units and ultra-small products.

## Stepping Actuators

### ■ Lineup of Stepping Motor Actuators

Immediately after the commercialization of Hi.T Drive, there was demand for a product with a stepping motor instead of a DC servo motor. In 1979, HDSI started to sell HT-14P and HT-20P as catalog products by mounting a motor manufactured by a manufacturer specialized in stepping motors. After that, HDSI has been delivering HarmonicDrive® speed reducer units without a DC servo motor to the stepping motor manufacturer until now.

As described earlier, HDSI has been developing and manufacturing DC servo motors and AC servo motors in-house, but procuring stepping motors from outside sources.

HDSI delivered its own stepping motor control device for a while because it was the same as the driver unit developed for RESPONSYN (as described in 2-2-2).

Although there is demand for stepping motors to be used for the linear actuators described later in addition to rotational actuators for Hi.T Drive, HDSI procures these motors from outside sources.

## AC Servo Actuators

### ■ RS Series

As DC servo motors started to be replaced with AC servo motors around 1980, HDSI commercialized the square flange-type RS series RS-14, 20, 25, and 32 with AC servo motors procured from outside sources in 1987. HDSI introduced the round flange-type mini series RS-8, 11, and 14 to the market in 1989 after developing in-house a motor appropriate for the size of HarmonicDrive® because none was available in the market.

Later, HDSI added the shaft output-type RSS-17, 20, 25, and 32 and the flange output-type RKS-20, 25, and 32 by combining it with the HarmonicDrive® S series as in the DC servo motor series.

By combining it with the thin CSF series of the HarmonicDrive® S series, HDSI introduced RSF-17, 20, 25, and 32 and the mini series RSF-8, 11, and 14 to the

market in 2003, RSF-5 in 2005, and RSF-3 in 2006 to expand the series.

The RSF-3 actuator was awarded the Organization for Small & Medium Enterprises and Regional Innovation Award of the Robot Award 2007. The detailed history of the development of RSF-3 is described in 2-1-3 in “HarmonicDrive® Products” (Figure 6).



Figure 6 RSF-3

## Brushless DC Actuators

### ■ FLA Series

In the 1990s, research institutes started research on human support robots. Around 2000, compact and lightweight HarmonicDrive® with high reduction ratios started to be used for research purposes. The applications included rehabilitation, carrying heavy objects, caregiving, and welfare. Later, in response to growing demand of research institutes and companies for HarmonicDrive® components, units, and actuators, HDSI has been supplying special-design products.



Figure 7 FLA series

In 2017, HDSI set up a plan to develop a standard human support actuator product as an effort to develop new markets in the future. HDSI learned about the characteristics of how they would be used based on marketing activities, and combined the two types, the HarmonicDrive® type and the HarmonicPlanetary® type, with a brushless DC motor.

As a result, HDSI developed a flat, lightweight, and low-cost actuator series, and introduced FLA-11, 14, 17, and 20 to the market in 2018 (Figure 7). The series was designed for specific applications based on concepts different from those of HDSI's existing actuators for general industrial machines and industrial robots, such as using a single row of deep-groove ball bearings as the main bearing on the output shaft side as well as the lack of an encoder.

## 2-2-2 Development of RESPONSYN

### Beginning of Development

“RESPOSYN” was a product developed and manufactured by USM. There were two types, the stepping motor type and the AC motor type. HDSI conducted a marketing survey in Japan based on the manual of USM. Upon launching the AP Group in 1978, HDSI positioned RESPONSYN as one of the core products (Figure 8).

### Technology Overview

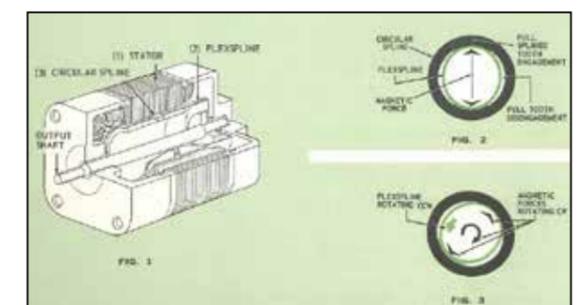


Figure 8

It was an electromagnetic HarmonicDrive® consisting of a pulse motor mechanism and HarmonicDrive®.

The name was coined by USM because it offered quick response and synchronous rotation with the frequency of the power supply.

The body of its flexspline was longer than that of regular HarmonicDrive® to reduce its rigidity for higher elasticity. A silicon sheet was wrapped around the inside diameter of the flexspline. A stator with excitation winding was placed with a slight gap with respect to the outer diameter of the body, and the circular spline was fixed to the end of the inside diameter of the stator. As the magnetic field of the excitation winding rotated, the silicon sheet around the inside diameter of the flexspline was pulled and deformed to form an ellipse, generating wave motion.

Because the equivalent moment of inertia of the rotor was extremely small compared to the regular stepping motor and the rotor and spline stator meshed with the spline across the major axis as in HarmonicDrive®, it provided steps with superior transient response. In addition, it had high pull-in torque for bearing relatively high inertial loads, and generated no resonance in the low-speed region.

HDSI developed and sold the driver circuit DU-200 series for domestic sales.

#### Commercial Applications

The products were adopted for the feed mechanisms of industrial fax machines for newspaper publishers, rotary presses, X-Y drive systems of automatic drafting machines, mirror drive/paper feed systems of phototypesetters, raising and lowering of the electrode and X-Y table of electrical discharge machines, roll interval control of continuous casting machines, electrode drive systems of electrical discharge machines, and watch case polishing machines.

#### Product Lineup

##### ■ Motors

HDM-15/155/170/175/185 series

##### ■ Driver units

DU-200/200A/200B/200E/200H series

##### ■ Driver modules

DM-100/200 series

#### ■ Pulse generator modules

PGM-100 Series

#### Other Highlights

HDSI sold the product until around 1990.

However, there were the problems of magnetic noise and gear meshing noise. These problems resulted from the structure of the product and were therefore irresolvable. Without the prospect of sales growth, HDSI discontinued the product around 1991.

## 2-2-3 Development of the FH2000 Series

#### Beginning of Development

Around 1984, low-speed and high-torque direct-drive motors (DD motors) came into the spotlight as “servo motors providing high positioning accuracy without backlash or wear of speed reducers,” and started to be used especially for horizontally multi-articulated robots. In addition, they were hollow and thin.

While investigating them as drive units of the future, HDSI decided to develop a hollow servo motor taking advantage of HarmonicDrive®, which could be used to easily achieve a hollow structure. HDSI aimed to commercialize the flat-type hollow AC servo actuator FH2000 series by combining them. The AC servo actuator had the characteristics of a DD motor and had high torque.

The letter F of the series name comes from “Flat,” the letter H comes from “Hollow,” and 2000 means that it was a flagship product of the 21st century.

#### Technology Overview

In 1987, HDSI started developing FHA-25A. HDSI developed the AC servo motor jointly with an external manufacturer where HDSI suggested winding methods, etc. After repeated prototyping, HDSI successfully developed the hollow motor.

By combining it with the flat and hollow HarmonicDrive®, HDSI released FHA-25A (Figure 9 and Figure 10) at the end of March 1990.



Figure 9 FHA-25A

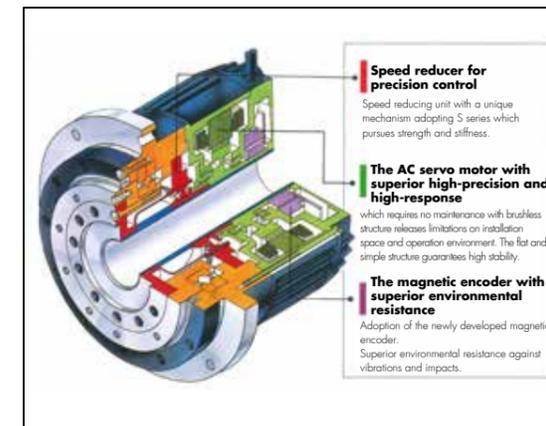


Figure 10

After that, HDSI launched a sales promotion project, where the development engineers conducted promotional activities and market surveys across Japan for a period of 13 months.

They visited manufacturers of semiconductor manufacturing equipment and machine tools. With a favorable market response, HDSI sold 250 units in one year.

Having higher torque and being more lightweight and compact compared to DD motors despite its hollow structure, FHA-25A contributed to the downsizing of customer devices.

At the time of introducing a new model of the hollow motor, HDSI decided to develop it in-house to reduce cost and improve performance as well as to shorten the development period for expanding the series, and has been accumulating technologies.

#### Commercial Applications

The products were adopted for robots, semiconductor manufacturing equipment, machines for the optoelectronics industry, and medical devices.

#### Product Lineup

After introducing FHA-25A to the market, HDSI proceeded with the development to expand the series in response to demand for smaller sizes, higher torque, large hollow units, and units with a brake.

After introducing FHA-40A to the market in 1992, HDSI expanded the series and offered more optional specifications by releasing in sequence FHA-14A, 17A, 25B, 32B, 40B, and 50A with the motors developed in-house in response to market demand. One of the major features of this series was the use of labyrinth sealing inside the high-speed shaft side to reduce internal loss.

After that, the FHA series has been one of the flagship products of the mechatronics business for 30 years until now.

#### ■ FHA-C Series

After releasing FHA-17C, 25C, and 40C with the ultra-thin HarmonicDrive® CSD series for higher flatness and hollowness in 2000, HDSI added FHA-32C.

The series had a shorter total length, larger hollow opening, and better performance characteristics.

#### ■ FHA-C mini Series

Aiming to expand the market to machines for the optoelectronics industry and medical devices, HDSI started developing a miniature version of the FHA series. HDSI reduced (flattened) the length in the axial direction by integrating the circular spline and housing and by using screws instead of tightening bolts for coupling the cross roller bearing, the flexspline and housing (Figure 11).

In 2003, HDSI completed the cube-shaped series. HDSI has been expanding the product lineup until now.



Figure 11 Comparison of FHA-8C (top) and RSF-8A (bottom)

### ■ SHA Series

HDSI developed the SHA series targeting industrial robot applications where the FHA-C series was not adopted. HDSI used the high-torque HarmonicDrive® SHG series for higher compactness and improved environmental resistance.

As a design concept, modular design of components allowed for more flexible combinations and easier expansion of the lineup.

The series incorporated the magnetic absolute encoder developed in-house.

After introducing SHA-25 to 65 to the market in 2009, HDSI introduced SHA-20 to the market, and has been expanding the series and offering more optional specifications until now (Figure 12).



Figure 12 SHA series

### ■ Sales of Stand-Alone Hollow Motors

As the hollow motors were appreciated, HDSI has been selling the stand-alone motor of the FHA series as the

MAA series since 1993 in response to customer demand.

In addition, HDSI has been selling the motor of the SHA series as the HMA series since 2018 after making it easier to handle as a stand-alone motor (Figure 13).



Figure 13 HMA series

## 2-2-4 Development of Positioning Devices

### Beginning of Development

#### ■ Rotational Positioning Devices

As measuring instruments, optical instruments, and semiconductor/LCD manufacturing equipment require high resolution and high repeated positioning accuracy, HarmonicDrive® components with high reduction ratios and superior angle transmission accuracy started to be used.

Under such circumstances, in response to growing customer demand for unit-type components, HDSI decided to work on the commercialization of precision positioning devices and actuators.

For customer devices, HDSI adopted the special pancake-type (FB-type) HarmonicDrive®, which was thinner and had higher precision.

However, as it was a unit-type product that required high positioning accuracy, table top runout accuracy, and parallelism, HDSI tried to commercialize a rotary table with the cup type (CS type) that had higher accuracy. For the rotary table unit, HDSI achieved the target runout accuracy for the table top by achieving a highly accurate

machined surface as the rolling contact surface of the thrust needle bearing by taking advantage of the precision grinding technology that HDSI had been accumulating and ingenious methods of production technology. In 1985, HDSI introduced the precision small index table “Fine Index  $\theta$  Table FIU-20” to the market (Figure 14).

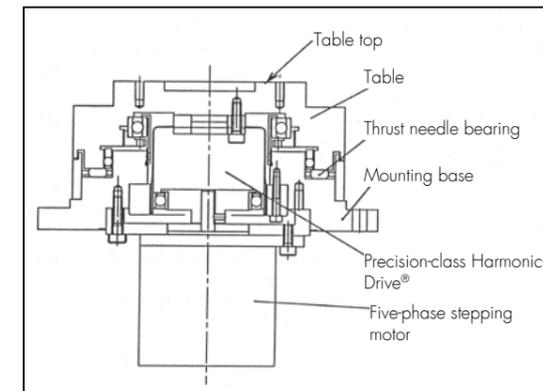


Figure 14 FIU

Later, while expanding the series and commercializing special index tables in response to customer demand, HDSI completed the series of FIU-14 to FIU32 in 1989.

#### ■ Linear Positioning Devices

While struggling to find new applications of the HarmonicDrive® CS-5 commercialized in 1984, the smallest size at the time, HDSI consulted with Professor Hiromasa Ito (at the time) of the Research Institute for Electrical Communication, Tohoku University, who had a relationship with the company, about possible applications of the CS-5 component and speed reducer. He gave advice, saying, “Why don’t you try attaching a screw to the output shaft to turn it into a linear drive? That might be one application.”

HDSI immediately started the development, but could not satisfy the target positioning accuracy just by using a high-precision screw. After accumulating related technologies while improving screw measurement and centering, screw housing, measurement method, and machining method, HDSI completed the linear actuator LA-30 in 1989. This was adopted for electron microscopes as advised by Professor Hiromasa Ito. Later, HDSI

developed the series of linear products by adding different strokes and driving forces based on the sizes of HarmonicDrive®.

### Technology Overview

LA-30 achieved a resolution of 0.0174  $\mu\text{m}$  (17.4 nm) and a stroke of 10 mm by combining the high reduction ratios of CS-5 and a precision lead screw. At the time, foreign-made linear actuators were imported, few of which had guaranteed nominal accuracy.

Later, HDSI developed LA-30B by replacing the precision lead screw with a ball screw for improved accuracy in 1994 (Figure 15). HDSI has been expanding the series focusing on the ball screw type.



Figure 15 LA-30B

### Commercial Applications

The product was adopted for specimen fine adjustment systems of electron microscopes. A special product based on LA-30B was adopted for the Subaru Telescope for the adjustment of flatness of the mirrors. After expansion of the lineup, it was adopted for injection molding machines, servo press machines, and printing machines.

### Product Lineup

The product lineup included the long stroke-type LA-32 and high driving force-type LAH-46 and LAH-80 in response to market demand.

#### ■ LBC

HDSI had been importing and selling linear actuators

developed by Harmonic Drive System GmbH in Germany since 1992 for applications requiring high driving force.

To lower the price and meet the demand in the Japanese market, HDSI proceeded with domestic production, and introduced LBC-25A with a maximum driving force of 12,000 N by adopting the HarmonicDrive® CSF-25 to the market in 1995. The applications included injection molding machines, servo press machines, and printing machines, where hydraulic drive systems were being replaced with electric motor drive systems.

#### Other Highlights

HDSI successfully developed the high-precision positioning device market by introducing the precision small index table (FIU-20) to the market in 1985 and the linear actuator (LA-30) in 1989.

In the electronic and optical instrument industries, there was growing demand for higher accuracy and higher precision.

Against this background, HDSI organized the Fine Positioning System (FPS) Team in 1990 to develop the fine positioning system business. The team developed a variety of stages as precision positioning devices applying the linear actuator LA-30, including the X/Y two-axis “nanometer stage” (Figure 16) in 1990, the finite-rotation “nanoradian stage” that took advantage of high-accuracy and high-resolution performance in 1991, the X/Y/Z three-axis “nano auto stage” in 1992, and the compact and lightweight one-axis unit “nano positioner” with high perpendicularity in 1993. All of them were thin with high stiffness and high accuracy.

While precision positioning devices, including the above, were expected to form a big market, HDSI dissolved the dedicated team by integrating the developed products and organization into the Mechatronics Division as a result of organizational changes due to adverse market conditions.

Later, due to the loss of price competitiveness caused by improved accuracy of the DD motors developed by competitors, HDSI discontinued the FIU index table and

various types of stages in 1995.

The linear actuator technology of converting rotation to linear motion was later applied to spot welding guns for automobiles in 2005.

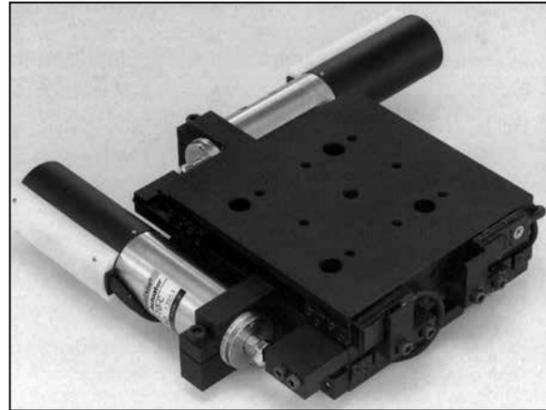


Figure 16 Nanometer stage

## 2-2-5 Development of Control Devices

### Beginning of Development

To drive a servo actuator, a driver unit for controlling the actuator is required. Initially, HDSI depended on OEM manufacturing by a servo motor manufacturer.

However, to expand the sales of actuators, Hi.T Drive, featuring high positioning accuracy and rotational accuracy, had to be bundled with a dedicated driver for optimal control of the actuator. As a result, HDSI started developing a driver unit in-house.

First, HDSI developed and sold the DU series for RESPONSYN imported from USM in 1978 to accumulate technologies.

The HT series, which HDSI introduced to the market in the same year, was initially an OEM product. HDSI proceeded with the development according to the policy described earlier, and released its own driver “HS series for DC servo motors” in 1982. “HS” indicated that it was a driver unit for servo motors with HarmonicDrive®.

### Technology Overview

HDSI added the analog input, digital input, and data

communication input units in sequence for high-precision positioning control and high-stability speed control utilizing the PWM control system.

### Product Lineup

#### ■ HS Series for DC Servo Actuators

##### ■ HS-90/HS-100 Series

HDSI released the series in 1978 based on OEM manufacturing for the actuator HT series.

The HS-90 series was a driver unit with a thyristor-switching driver circuit, and the HS-100 series was a driver unit with a linear transistor driver circuit.

##### ■ HS-200 Series (for DC Servo Motors)

HDSI started developing in-house the HS-200 series in 1982. By adopting the linear transistor circuit, HDSI introduced HS-220, HS-240, and HS-250 to the market in sequence from the same year.

HDSI introduced the serial pulse command HS-300 series to the market in 1984, and the HS-400 series, which allowed for motor control with PC commands, in 1987 to meet demand in the semiconductor manufacturing sector, which was growing rapidly at the time.

##### ■ HA Series (for AC Servo Motors)

The HA-200/300 of the driver unit HA series for AC servo actuators, released in 1987, were OEM products manufactured by a motor manufacturer. As one-chip microcomputers and IPMs became commercially available in 1993, HDSI developed the HA-600, a small unit allowing for position, speed, and torque control, jointly with a control device manufacturer, and introduced it to the market.

In 2000, HDSI adopted the RISC microprocessor to improve the performance, and introduced HA-650 by combining it with the FHA-C series with the newly developed wire-saving encoder to the market.

In 2003, HDSI introduced HA-655 with an ASIC to support 14-wire encoders to the market along with the FHA-C mini series. In 2008, HDSI introduced the advanced driver HA-800 with a FPGA to support A-format encoders in combination with the SHA series to the

market.

#### ■ Lineup for the Collaboration with Servo Motor Manufacturers' Drivers

Generally speaking, industrial machinery manufacturers select an AC servo motor appropriate for the system and cost, and control it with a host controller. The servo driver for controlling the host controller and motor is connected to the proprietary communication protocol of the servo motor manufacturer or the open-field network to achieve wire-saving, reliability, and ease of use. In order for HDSI's actuators to be widely used by industrial machinery manufacturers, the servo driver had to support various communication protocols.

To meet this need, HDSI introduced models of the servo driver HA-800/680 series that supported communication protocols of several manufacturers to the market from 2006 to 2009.

In 2012, there was demand for driving the hollow AC servo motor developed by HDSI with a driver of a servo motor manufacturer. In response to the demand, HDSI changed the encoder communication protocol of the hollow AC servo motor to the manufacturer's specifications to allow for connections. This was the beginning of collaboration with servo motor manufacturers' drivers. Later, HDSI collaborated with several servo motor manufacturers, and has been conducting new collaboration activities until now.

This gave industrial machinery manufacturers and end users a wider selection of HDSI's actuators, contributing to the expansion of the mechatronics business around the actuators.

## 2-2-6 Development of the Direct-Drive Motor KDU Series

### Beginning of Development

As described in 2-2-3, HDSI developed the flat hollow actuator FH2000 series as direct-drive motors (DD motors) came into the spotlight around 1984, and has been expanding the series until now.

In the same period, HDSI was considering linear and rotary DD motors with no speed reducer based on the outlook of the semiconductor manufacturing equipment and flat panel display manufacturing equipment markets, where increasingly higher accuracy was required.

Under such circumstances, HDSI obtained information from a Slovenian engineer who worked for HDSI that a laboratory in Slovenia had conducted research on DD motors and acquired a patent. As a result of reviewing the patent, HDSI found that the patent as applied in a DD motor had superior characteristics. HDSI signed an exclusive license agreement for the patent and a cooperation agreement with the inventor, started the development in 1996, and commercialized KDU-13 in 2006.

#### Technology Overview

Due to its unique structure and winding method, KDU produced higher power than the DD motors that were commercially available at the time.

However, regular winding machines could not wind the uniquely designed winding efficiently.

Under such circumstances, HDSI found a research paper on transformer winding techniques by a university professor, signed a license agreement limited to motors, and developed a special winding machine with support from the professor, which allowed for the production of KDU.

With an ultra-high-resolution encoder (8.38 million divisions/revolution), KDU achieved an absolute positioning accuracy of 10 sec, repeated positioning accuracy of  $\pm 0.5$  sec, and motor output surface runout accuracy of  $2 \mu\text{m}$  or less. The precision machining techniques of HDSI were also utilized to achieve accuracy, making it a unique DD motor with a larger hollow opening. In the name “KDU,” the “K” comes from the initial of the developer, the “D” comes from the initial of the Slovenian engineer who was the inventor participating in the development, and the “U” comes from “Unit.”

#### Product Lineup

In 2010, HDSI introduced new models KDU-13SB/WB

with higher resolution (11.84 million divisions/resolution) to the market (Figure 17 and Figure 18) to improve the quality of the sensor and the serviceability of the servo amplifier.

In 2011, there was the demand of a specific customer for a repeated positioning accuracy of  $\pm 0.35$  sec. HDSI achieved it by employing a dual-head encoder system and released it as KDU-13SC.

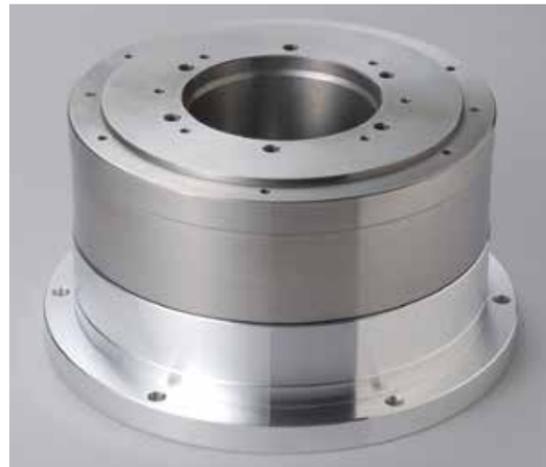


Figure 17 KDU

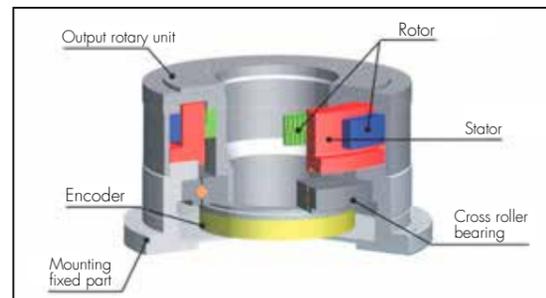


Figure 18

#### Commercial Applications

The products were adopted for the index tables of assembling equipment of semiconductor manufacturers, precision measuring instruments for semiconductor optical parts, and encoder zero-position testing instruments.

## 2-2-7 Development of the LSA for Laser Scanners

#### Beginning of Development

HarmonicDrive® has the characteristics of an excellent speed increaser in addition to its functionality as a speed

reducer.

A machine tool manufacturer asked for the development of a fast-response micro-step actuator (MSA) by taking advantage of the speed increasing characteristics.

Amplifying the microscopic displacement of the piezoelectric actuator with an extremely narrow range of motion from the low-speed shaft of HarmonicDrive® allowed for high-precision angular operation with a large angle of rotation of up to 10 degrees. This motion was used to drive the mirror of a laser scanner at high speed to oscillate the laser beam.

HDSI developed the MSA for laser scanners, which had never been commercialized in Japan, and exhibited it at exhibitions in 1990 to check the market response.

However, unable to achieve the target performance, HDSI abandoned the development because of difficulties in adjustment during product assembly, the rotation angle not reaching the target value, unstable positioning accuracy, and poor response.

#### Technology Overview

Unable to resolve technical problems of the MSA, HDSI started developing a laser scanning actuator (LSA) based on the motor and encoder technologies that HDSI had been developing.

With the prospect of resolving the problems of the MSA by devising a special encoder for the finite-angle rotary servo motors, HDSI switched over to the development of a new actuator.

HDSI acquired a patent for the finite-angle motor incorporating this encoder.

Although there were some problems during the course of the development such as shifting of the zero position due to temperature drift, HDSI introduced the optical galvano scanner LSA-50A (Figure 19 and Figure 20) to the market in 1994 by creating new technologies. At the same time, HDSI introduced two models of drivers to the market.

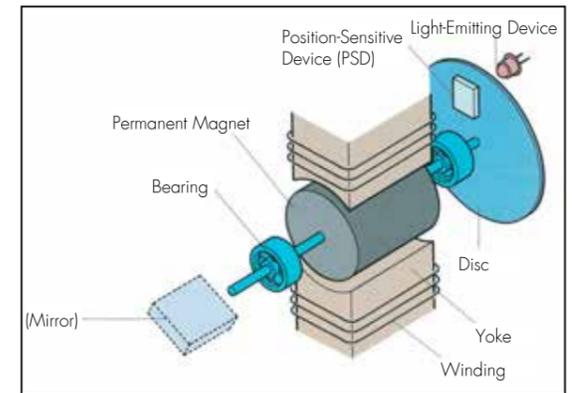


Figure 19

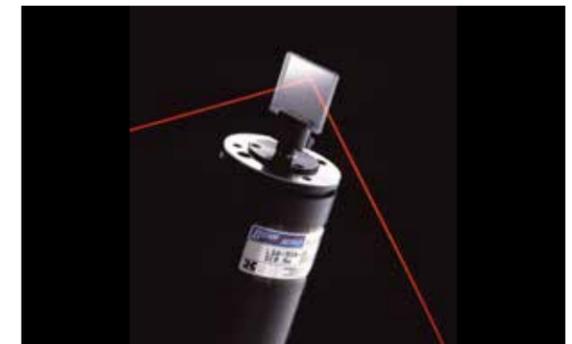


Figure 20 LSA

#### Commercial Applications

The products were adopted for the mechanism for changing the oscillation angle of the laser beam of laser marking machines (used for plastic bottles).

#### Product Lineup

HDSI commercialized LSA-20A in 1999, and LSA-10A in 2004.

In 2002, LSA-20B for a specific customer was adopted after the required target of fast response was reached. HDSI has registered the trademark “BEAM SERVO®” for the LSA series.

#### Other Highlights

##### Linear Lens Drive Motors

In 2004, the manufacturer of laser marking machines using HDSI’s LSA in two axes created new demand. It was for a linear drive motor for the Z-axis to achieve 3D marking by moving the lens for active focusing in addi-

tion to X-Y flatbed scanning.

The required specifications included high speed, fast response, and high precision. Because such a motor was not commercially available at the time, HDSI decided to develop it in-house.

HDSI developed a linear sensor with a high-driving-force voice coil motor and an encoder based on the principle of the LSA sensor (Figure 21).

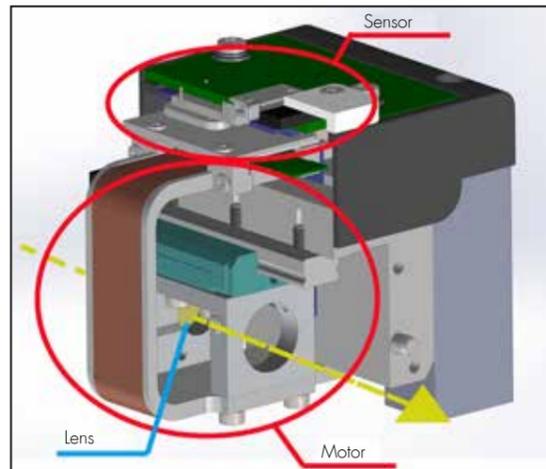


Figure 21

To achieve positioning with micrometer precision at a speed of several hundreds of Hz, HDSI achieved the required specifications by resolving the problems of the bearing life and resonance suppression control, and started delivering the product in 2006.

HDSI acquired a patent for the mechanism as a linear actuator, which has been contributing greatly to the sales of the mechatronics products along with the rotary LSA.

## 2-2-8 Development of Encoders (Sensors)

### Beginning of Development

The encoder of the actuator HT series introduced to the market in 1978 was an OEM product procured from outside sources. However, because encoders were one of the important technologies of actuators, HDSI decided to concurrently develop them in-house taking the opportunity of developing the RH series actuators in 1984.

While adopting appropriate technologies for its own

actuators, accumulating technologies, and acquiring new technologies, HDSI started to choose from encoders developed in-house and OEM products from specialized manufacturers.

### Technology Overview

Initially, HDSI used phototransistors for the RH series. Due to the lack of precision, HDSI decided to develop a differential encoder using photodiodes. However, because the production of photodiodes required initial costs, HDSI decided to develop it jointly with a manufacturer specialized in encoders.

### Product Lineup

#### ■ Micro Encoder ME Series

In 1984, HDSI developed the ME series as the encoder used for the servo actuator RH series. This micro encoder to be built into the motor was jointly developed. OEM products manufactured by the specialized manufacturer were used.

As stand-alone products, HDSI released MES-6 and MES-9 based on OEM manufacturing.

They were used for special applications such as a special product developed in response to demand for a dedicated instrument for track gauge measurement.

Being the world's smallest encoder at the time, MES-6 greatly contributed to the development of the actuator RSF-3 as described earlier.

As sensors are important elements of motion control, as discussed earlier, and significantly influence the characteristics of HDSI's mechatronics products, HDSI has been working on the development of such technologies. HDSI has registered the trademark "Harmonicsyn<sup>®</sup>" for MES-6.

#### ■ Magnetic Encoders

The actuators of HDSI consisted of a speed reducer and motor, which required a lubricant such as grease. This posed a problem of deposition of lubricant oil on the optical encoder. To resolve this, HDSI developed in-house a magnetic encoder with environmental resistance.

In 2005, HDSI used this magnetic encoder for the actuator for industrial robots for a specific customer.

HDSI successfully made the actuator compact by placing the sensor detection unit inside HarmonicDrive<sup>®</sup>. HDSI resolved problems such as deterioration of parts due to being immersed in grease and oil leakage from the sensor lead wires by making improvements.

At the same time, HDSI tried to improve the functionality such as fail-safe design, temperature/speed anomaly detection, and battery-based constant multi-revolution counting.

HDSI improved the magnetic encoder for the actuator SHA series in 2009, improving its position detection resolution from 13-bit to 17-bit by adopting a multipole sensor magnet. However, for SHA, HDSI placed the sensor detection unit behind the motor to resolve the problems described earlier. HDSI resolved the problem of the effect of magnetic noise from the electromagnetic brake placed nearby by using multiple sensors for compensation. More recently, HDSI has been improving the encoder to support the serial communication formats of different manufacturers so that it can be connected to their servo amplifiers. As a result, it has been contributing to the development of the actuators.

#### ■ Torque Sensor Units

A typical torque sensor used for torque management and control of power transmission systems consists of strain gauges for measuring torsional stress attached to a thin shaft that can easily become twisted. Despite the availability of dedicated units and high accuracy, such a sensor had to be added to the power transmission system, making it larger in size.

In contrast, because the flexspline of HarmonicDrive<sup>®</sup> was thin walled, torsional stress caused by load torque could easily be detected, and just attaching strain gauges allowed for torque measurement. It was compact and lightweight, it did not require any additional torsional component, the stiffness of the entire unit was not decreased, and it was integrated with a speed reducer, making it easy to build into a device.

Professor Minoru Hashimoto of Kagoshima University started the research on this method of using the flexspline

of HarmonicDrive<sup>®</sup>, which resulted in joint research with HDSI.

Professor Minoru Hashimoto later moved to Shinshu University. He has been working on the joint research and application development until recent years. HDSI commercialized the HarmonicDrive<sup>®</sup> unit with a torque sensor in 2000 (Figure 22).

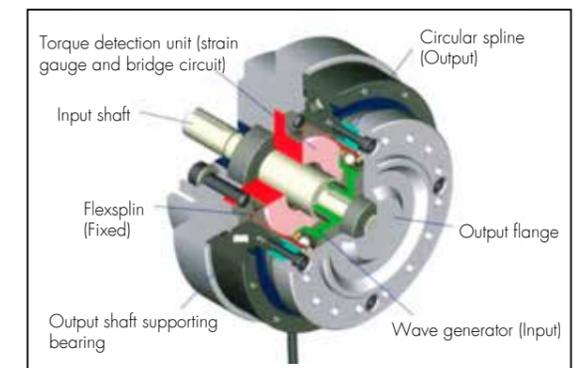


Figure 22 Torque sensor unit

## 2-2-9 Precision Planetary Speed Reducers AccuDrive<sup>®</sup> Used for the Lineup of Actuators

### Beginning of Development

Servo actuators consisting of HarmonicDrive<sup>®</sup> and a servo motor had superior performance at low output speed due to the high reduction ratios of HarmonicDrive<sup>®</sup>. HDSI aimed to meet a wide variety of market demand by offering a series of actuators by incorporating AccuDrive<sup>®</sup> with low reduction ratios for faster applications.

### Product Lineup

#### ■ CPM Series

In 1992, targeting the market requiring high rotation speed (80 r/min or higher), HDSI developed actuators incorporating the AccuDrive<sup>®</sup> HP series by using the motor used for the DC and AC servo actuators with HarmonicDrive<sup>®</sup>.

The CPD type was the DC servo motor specification, and the CPA type was the AC servo motor specification.

In the same period, a motor manufacturer decided to adopt the high-torque type HP-A of the planetary speed

reducer HP series, which had been under development, as an OEM product, and HDSI started supplying the speed reducer units.

Accordingly, HDSI decided to specialize the AccuDrive® HP speed reducers to be sold as gear heads, and sell the CPD and CPA types as customized products.

In 1993, based on the conclusion that the series had to be expanded, HDSI decided to make a bulk purchase of the actuators sold by the motor manufacturer as OEM products and sell them.

It was the CPM series with Sizes 14, 16, 20, 25, 32, and 40 (Figure 23).

The sales of the CPM series stalled because HDSI could not satisfy the cost requirement of the market nor provide sufficient services in terms of control.



Figure 23 CPM series

#### ■ RJ-16

After introducing CPM to the market, HDSI introduced RJ-16 to the market in 1997 by using only the actuator Size 16 with a low-cost AC servo motor in response to demand for low cost.

HDSI aimed to offer a low-price product with high acceleration torque and feedback control with no loss of steps, which could surpass the stepping motor actuators. However, the product did not become as popular as expected, and HDSI discontinued its manufacture in 2000.

#### ■ SHA-25/32-HP

HDSI introduced SHA-25 and SHA-32 to the market in 2011 as the faster series of SHA consisting of the flat hollow planetary speed reducer HPF series and a hollow servo motor. The encoder was of the magnetic type.

#### ■ FLA Series

The FLA series as described in 2-2-1 also had the planetary speed reducer series.

### 2-2-10 History of Mechatronics Products

Starting with the development of servo actuators according to the management policy of 1977, HDSI has been expanding the product lineup while acquiring, accumulating, and expanding technologies required for motion control of motors, control devices, and sensors, in addition to the existing mechanical technologies and skills for speed reducers and mechanical components.

The early servo actuators were directly coupled to the servo motor to take advantage of the compactness and light weight of HarmonicDrive®. Later, HDSI introduced innovative actuators to the market by developing hollow servo motors and hollow sensors that helped take advantage of the characteristics of HarmonicDrive®, which could be used to easily achieve a hollow structure. HDSI developed linear actuators in addition to rotary actuators, which allowed the company to enter new markets by expanding the range of controlled motion.

The mechatronics products have been contributing to the expansion of the business domain by allowing for unique optical scanners by matching the accumulated motor and sensor technologies with market demand for products.

These products were made possible by integrating the mechanical expertise of HDSI with the newly accumulated electronic technology including software.

In the future, HDSI will continue to deliver products to the precision control market by improving techniques and improving and expanding mechatronics technology, which is the core technology of “Total Motion Control.”

## 3. AccuDrive® (Planetary Gear) Products

### 2-3-1 Development of the Early Planetary Speed Reducers, the BP, and MH Series

#### Beginning of Development

HDSI had been conducting sales activities for HarmonicDrive® by emphasizing its compactness, light weight, and high reduction ratios as selling points. While high reduction ratios were appreciated in the market, there was a growing demand for low reduction ratios for faster applications. Also, there was an increasing demand for low reduction ratios in areas where other speed reducers were used.

Initially, the lowest reduction ratio of HarmonicDrive® was 80. To meet the demand, HDSI conducted research on low reduction ratios in HarmonicDrive®, and commercialized the reduction ratio 60 and 50 series in 1982.

However, in the speed reducer market, the market size for lower reduction ratios was overwhelmingly larger.

Achieving this was not easy with HarmonicDrive® due to its mechanism. Around 1980, HDSI started investigating speed reducers allowing for low reduction ratios across the globe. HDSI found more than a dozen unique and interesting products, all of which were not suitable for motion control.

When consulted about the situation, Hiroshi Kameda, who was involved in the introduction and development of HarmonicDrive® and had been working as an assistant professor of structural engineering at the University of Tsukuba since 1978, advised, “Based on the actual situation of HarmonicDrive® and the technologies accumulated by Hasegawa Gear Works, planetary speed reducers would be suitable, although orthodox.”

In 1986, HDSI started considering solely planetary gear speed reducers, and started the development after acquiring the technologies for the mechanism based on a patent by Machinery Engineering Corporation (later

called BP speed reducers) and the mechanism based on the patent for “profile shifted internal gears” by Professor Muneharu Morozumi of Shinshu University (later called MH speed reducers). In 1987, Hiroshi Kameda, who had rejoined HDSI, started participating in the development.

#### Technology Overview

#### ■ BP Series

The feature of this mechanism was the technology for removing backlash by adjusting the center distance from the outside.

In 1988, HDSI released two models with reduction ratios of 7.2 and 9.0 and a backlash specification of 1 arc-min or less as the BP series, and standardized the stepping motor speed reducer and double-shaft speed reducer (Figure 1).



Figure 1 BP series

In 1987, HDSI acquired the trademark right for AccuDrive® as planetary gear speed reducer products other than HarmonicDrive®, and started the gear speed reducer business.

### Other Highlights

The BP series was not suitable for high load capacity and it was difficult to improve positioning accuracy and speed variation. The product did not evolve, and was discontinued in 1999 because of the later commercialization of other planetary speed reducer series.

### ■ MH Series

This mechanism was called the small tooth differential planetary gear speed reducer mechanism, where the difference in the number of teeth between the internal gear and planetary gear was 0 to 6.

For the double-stage type, this technology allowed for reduction ratios of 20 to 1000 or higher depending on the selection of the numbers of teeth of the first- and second-stage gears.

The development objectives were reduction ratios of 25 to 60, low inertia, high rigidity, low vibration, high efficiency, compactness, and light weight.

The prototype had a reduction ratio of 40 and zero tooth differential in the second stage. In other words, the second stage was a type of coupling converting eccentric motion of the first-stage planetary gear to the fixed axis of rotation. However, there were problems of insufficient strength of the second stage, low efficiency, and high backlash. As a result, the zero tooth differential mechanism in the second stage was changed to the pin-and-hole type W mechanism, which was already set to be applied to other products.

The W mechanism is a generic term for mechanisms for transmitting rotation between two parallel shafts, e.g.

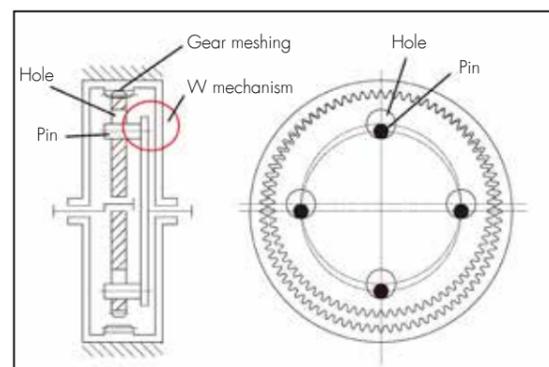


Figure 2 Pin-and-hole type W mechanism

universal joints, Oldham coupling, and pin-and-hole type. HDSI adopted the pin-and-hole type for the prototype of the MH planetary speed reducer (Figure 2).

HDSI kept making improvements by using the design and strength calculation methods of Professor Muneharu Morozumi, as well as by adopting the W mechanism. However, unable to resolve the problems, HDSI decided to cancel the series as speed reducers for control in September 1988.

### Commercial Applications

Although the objectives as speed reducers for control could not be achieved, there remained the application for wheel actuators for automated guided vehicles.

For this application, HDSI had already delivered wheel actuators with HarmonicDrive®. The user asked for a lower price and higher efficiency. HDSI proposed a MH speed reducer that would easily fit into a wheel and proceeded with the development.

HDSI developed a compact structure using the pin-and-hole type W mechanism in which the rotating internal gear was fixed to the wheel as an output.

As the advantages of the structure were appreciated, HDSI started to receive inquiries from more than a dozen companies around 1986. After making improvements, HDSI delivered prototypes in 1987. Several companies adopted the product on an ongoing basis, but HDSI could not lower the price. Without the prospect of market expansion, HDSI decided to stop the sales expansion activities, but continued to deliver the product only to customers with ongoing relationships until around 2015 (Figure 3).



Figure 3 Wheel actuator

## 2-3-2 Development of the HP Series

### Beginning of Development

The torque capacity of the BP series was not very high. HDSI developed a unique planetary speed reducer with the backlash adjustment mechanism by studying the characteristics and structures of the existing products in the market. The design and structure had the following features:

- (1) The output bearing was placed on both sides of the second-stage speed reducer to achieve a thin structure as well as to increase the moment stiffness of the output.
- (2) The structure allowed for backlash adjustment from the outside after the assembly as in the BP series. It had four planetary gears. As a result of backlash adjustment, each pair of opposing planetary gears rotating in the forward or reverse direction share the torque.
- (3) The standard output of the speed reducer was flange output, and a shaft was installed to the flange when shaft output was required.
- (4) The first stage of the speed reducer mechanism was placed on the output side of the planetary speed reducer away from the motor mounting side and the second stage was placed on the motor mounting side to contain the required length for coupling the motor output shaft and first-stage sun gear inside the speed reducer. This allowed for a flat overall structure.

In 1990, HDSI commercialized Sizes 16, 20, 25, and 32 as the HP series (Figure 4 and Figure 5).

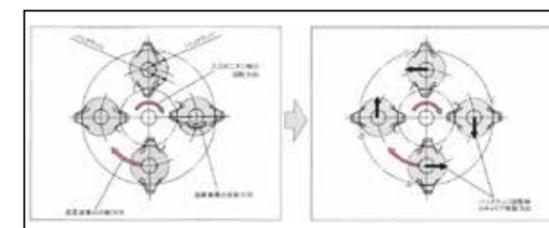


Figure 4 HP backlash adjustment mechanism

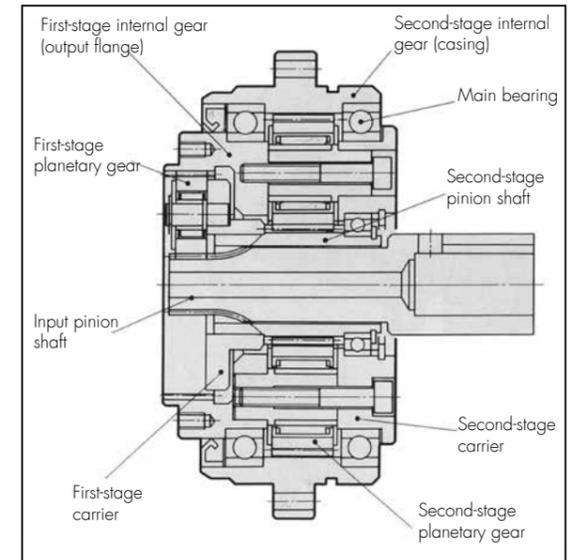


Figure 5 HP series

### Commercial Applications

Size 16 was widely used for applications such as the handling of semiconductor wafers.

The series was also adopted for the large-scale optical/Infrared telescope “Subaru.”

### Product Lineup

In 1991, HDSI commercialized the large sizes of Sizes 40, 50, and 65.

## 2-3-3 Development of the HP-A Series

### Beginning of Development

As HDSI commercialized the HP series, a motor manufacturer commercialized a revolutionary small servo motor. To combine the servo motor and the HP series, the HP series had to be balanced in shape with the motor and have a higher capacity. To achieve this, HDSI started to work on improving the HP series.

### Technology Overview

The HP series had problems of having the outside diameter of the speed reducer larger than that of the motor and not having sufficient torque capacity. HDSI changed the shape of the planetary speed reducer from round to square, and placed the first stage on the motor mounting

side to improve torque capacity.

It was adopted by the servo motor manufacturer, but HDSI kept improving the gear machining and bearing structure to resolve the remaining problem of high noise levels. As a result, HDSI succeeded in developing the HP-A series that was more lightweight and compact compared to the conventional planetary speed reducers for small servo motors, and featured high load capacity, high-precision, high rigidity, and the proprietary backlash adjustment function. The speed reducer unit was called HP-A, and the type with a motor flange was called CP (Figure 6).



Figure 6 HP-A series

#### Commercial Applications

The series was adopted for precision drive units of automated machines, travel drive mechanisms, and wrist drive mechanisms for scalar robots.

#### Product Lineup

HDSI commercialized Sizes 14, 16, 20, 25, 32, 40, and 50.

### 2-3-4 Development of the HP-C Series

#### Beginning of Development

In Japan, several servo motor manufacturers were competing for market share. Under such circumstances, the servo motor manufacturer that adopted the HP-A as a gear head for high-precision positioning asked for the development of a general-purpose speed reducer with a

lower cost. As for backlash, the precision equivalent to the HP-A series was not required.

#### Technology Overview

HDSI started the development around 1995. The objective was a low cost general-purpose type with a backlash specification of 15 arc-min or less. Based on the structure of the planetary gear mechanism, HDSI tried to reduce the cost by eliminating the backlash adjustment mechanism, integrating the output shaft and carrier, die-casting the housing, eliminating the mounting bolts for the internal gear, and using common parts by making the numbers of teeth of the internal gear, planetary gear, and pinion gear the same in the first and second stages, and introduced it to the market in 1996 (Figure 7 and Figure 8).



Figure 7 HPC series

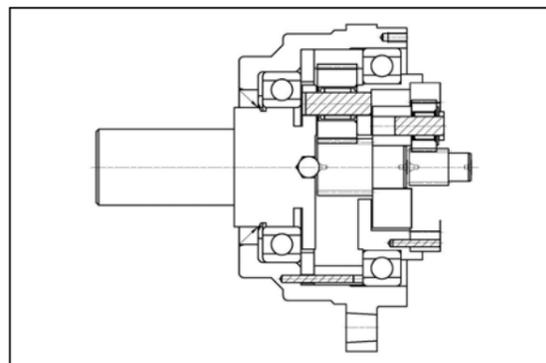


Figure 8

As there were some users adopting it other than the existing ones, HDSI momentarily expected it to be widely adopted. However, unable to secure sufficient orders to maintain the target manufacturing cost, HDSI discontinued it in 1998.

### 2-3-5 Development of the HP-F Compact Series

#### Beginning of Development

HDSI developed a small gear head for dealing with the commercialization of small motors (5w/10w) by a servo motor manufacturer.

#### Technology Overview

HDSI commercialized HP-11F that was balanced in shape with the motor in 1997, and HP-8F in 2003 (Figure 9).

The structure was orthodox, where the same planetary speed reducer mechanisms were placed in series and two ball bearings were used in series for the output shaft. Because the series was small with no backlash adjustment mechanism, HDSI introduced it with a backlash specification of 30 arc-min.

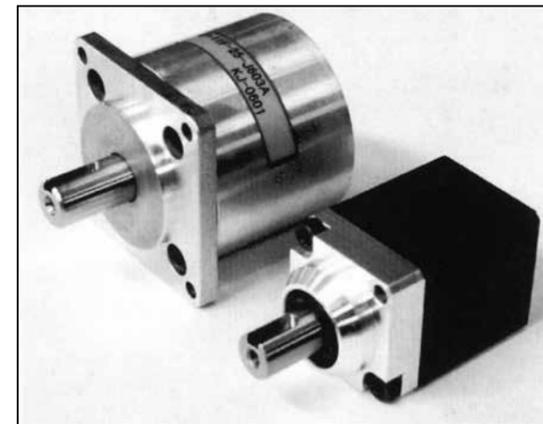


Figure 9 HP-F series

#### Commercial Applications

After the commercialization of the HP-F series, its sales did not grow significantly. Some of the reasons included that there were only two reduction ratios of 5 and 25 and that the small servo motor market at the time was not very large.

#### Other Highlights

Later, around 2003, there was a product using the mechanism of HP-F that greatly contributed to the planetary speed reducer business. It was the LCD open/close mechanism for aircraft.

The development was motivated by the problem faced by an electric appliance manufacturer providing instrumentation related to in-flight amenities regarding the smoothness and noise of its LCD open/close mechanism. When visiting HDSI's booth at a speed reducer exhibition, the manufacturer asked HDSI to develop a product for them.

HDSI decided on the development because it might be adopted in the aviation industry other than factory automation although the application did not require positioning accuracy.

Initially, the manufacturer requested only the speed reducer. Later, HDSI started to share the challenges in the conventional open/close mechanism with the customer. As a result of this relationship, HDSI ended up developing the system including the motor, clutch, and brake in addition to the speed reducer unit.

HDSI designed the entire system based on HP-F taking into consideration the total cost and reduction ratio, but the cost was higher than that of the conventional products. Achieving smoother movement and higher reliability, HDSI started delivering the LCD drive unit HP-11F in 2005, which was well-received and widely adopted continuously until now, contributing to the expansion of the planetary speed reducer business (Figure 10).

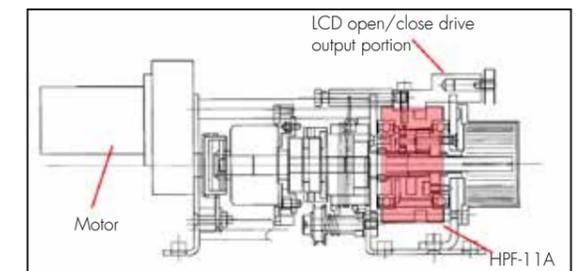


Figure 10 LCD drive unit HP-11F

### 2-3-6 Development of the HPG Series

#### Beginning of Development

The customers of planetary speed reducers were mostly regular and demanded lower cost.

At the same time, there was a growing demand for speed reducers with higher torque and lower backlash because of servo motors having higher torque.

To deal with motors with high torque, HDSI started developing a speed reducer with higher torque capacity and lower backlash.

#### Technology Overview

During the development, HDSI achieved improved torque capacity by increasing the number of planetary gears transmitting power from 2 to 3, and lower backlash by applying the elastic gear (flexspline) technology that it had been accumulating for HarmonicDrive®.

HDSI adopted the tandem structure with planetary speed reducer mechanisms placed in series, rather than the combined planetary speed reducer mechanism adopted for HP-A and HP-C. In the structure, the first-stage internal gear and second-stage internal gear were integrated, having the same numbers of teeth. Low backlash (3 arc-min or less, or 1 arc-min or less for special specifications) was achieved without the backlash adjustment mechanism by using thin-walled elastic internal gears. After establishing the machining techniques for elastic internal gears and improving machining accuracy for other parts, HDSI introduced the low-backlash, high-torque HPG series to the market in 1999 (Figure 11).

Another feature of HPG was its compact size achieved by adopting cross roller bearings (CRBs) integrated with the carrier for the output shaft. The CRBs took advantage

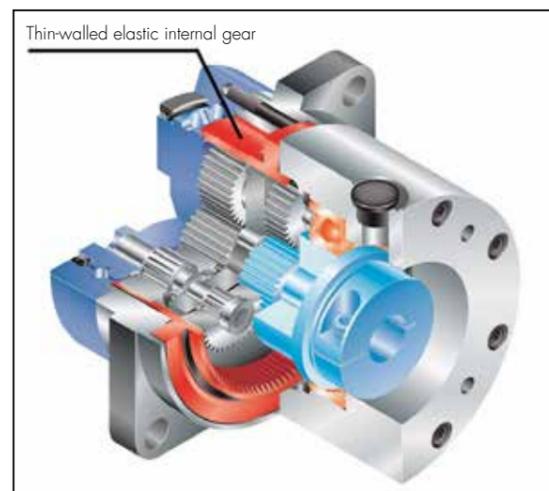


Figure 11 HPG series

of the technology that HDSI had been accumulating for the unit type HarmonicDrive®.

HPG has been adopted by many manufacturers to date.

In 2000, HDSI acquired the trademark right for HarmonicPlanetary® for the product family.

#### Product Lineup

To expand the lineup of the HPG series, HDSI commercialized the following types in addition to the double-shaft type and large sizes HPG-50A and 65A:

##### ■ HPG-RA Orthogonal

In response to a demand for bending the motor's axis of rotation to a right angle in terms of machine layout, HDSI developed the orthogonal unit by using bevel gears between the motor and speed reducer (Figure 12).

HDSI delivers it for special applications although it is not widely used in the market.



Figure 12 HPG-RA orthogonal

##### ■ HPF Hollow Planetary Speed Reducers

Structurally, it was difficult to adopt a hollow structure for the planetary speed reducer because of the sun gear at the center. However, there was a demand for passing wiring or piping through the speed reducer.

While it was difficult to achieve a hollow structure while maintaining precision and strength, HDSI devised a design where the sun gear had a hole in the center by adding twists to the reduction ratio and the number of teeth.

In 2011, HDSI introduced the flat and hollow HPF, which was based on HPG, to the market (Figure 13).



Figure 13 HPF

The HPF has been developed into hollow actuators in combination with hollow motors as HDSI's mechatronics products. The product complements the intermediary areas between hollow actuators (FHA actuators), which combine the hollow motor with low speed and high torque capacity with HarmonicDrive®, and the DD motor with low torque capacity and high speed.

HDSI has developed basic technologies for providing a wide variety of hollow speed reducers through the development of the HPF.

##### ■ HPGP

HDSI developed the HPGP aiming at higher torque than the HPG series, and introduced it to the market in 2012.

The torque of the HPGP has been increased by a factor of 1.3 compared to conventional products by increasing the number of planetary gears from 3 to 4.

##### ■ HPG-R Helical

To achieve noise reduction and higher torque, HDSI started developing a speed reducer using helical gears. As a result of establishing the machining techniques for thin-walled helical internal gears, which was technically difficult, HDSI succeeded in commercializing the single-stage helical speed reducer HPG-R, and introduced it to the market in 2015.

While there were only two reduction ratios in the conventional HPG series single-stage speed reducer, HDSI offered eight reduction ratios (reduction ratios of 3 to

10 in increments of 1) for the single-stage helical speed reducer in response to market demand.

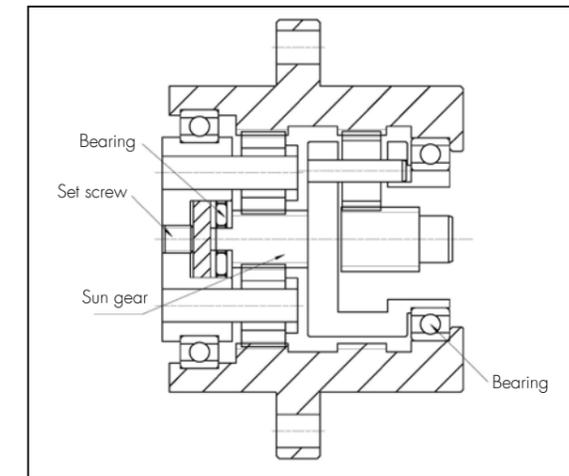


Figure 14

HDSI completed the development of the double-stage helical speed reducer for high reduction ratios in 2020, and introduced it to the market in March 2021 (Figure 14). Because the helical gear had a slanted tooth trace, the sun gear behaved similarly to a screw, causing axial displacement such as moving forward or backward while rotating. One of the challenges to achieving backlash of 3 arc-min was how to suppress the axial displacement of the sun gear. HDSI achieved backlash of 3 arc-min in the double-stage helical speed reducer by supporting the sun gear and the carrier coupled with it by two bearings at both ends. This structure excelled in the suppression of axial vibration compared to the competitors' speed reducers that used one bearing to suppress the axial displacement of the sun gear.

For the double-stage type, HDSI offered reduction ratios of 15 to 50 in increments of 5 to offer a full range of reduction ratios.

#### Other Highlights

In 2001, the HPG series was awarded the JSPE Technology Award (Figure 15). It was awarded for its contribution to compactness and light weight, low vibration and low noise, and long life in industrial machines because of its higher transmission torque capacity and angle transmission accuracy compared to conventional products.



Figure 15



Figure 16



Figure 17 HPG series

In 2004, it was also awarded a Good Design Award (Figure 16 and Figure 17).

### 2-3-7 Development and Overseas Expansion of the HPN Series

#### Beginning of Development

After the HPG series was introduced to the planetary gear speed reducer market in Japan, major Japanese servo motor manufacturers started to adopt it.

However, it was not popular in overseas markets. In the planetary gear speed reducer market overseas, there were many applications requiring lower precision and higher backlash than the HPG series.

Against this background, HDSI started to consider general-purpose planetary gear speed reducers for the

Asian markets excluding Japan in 2011.

As a result, in February 2013, HDSI established the manufacturing company SAMICK ADM Co., Ltd. jointly with SAMICK HDS Co., Ltd., a distributor of HDSI's products.

#### Technology Overview

To capture the market early, HDSI set development objectives of making the specifications compatible with competitors' products in terms of mounting dimensions and making the price competitive.

HDSI adopted helical gears as the competitors. The development was easy because it was a mid-range product and did not require thin-walled internal gears. HDSI introduced the HPN series to the market in 2013 (Figure 18).

In terms of performance, HDSI focused on high reliability to ensure that backlash would not increase if the speed reducer was used until the expiration of its lifecycle.

The reliability of the HPN was appreciated after it was introduced to the market, and gradually started to be widely adopted.

The HPN-RA orthogonal has been added to the lineup (Figure 19).



Figure 18 HPN



Figure 19 HPN-RA orthogonal

#### Special Notes

As described in 2-2-9, AccuDrive® planetary speed reducers have also been used for the lineup of mechatronics actuators of HDSI.

### 2-3-8 History of AccuDrive®

As a result of developing AccuDrive® with low backlash and low reduction ratios to enter the market for lower reduction ratios in addition to HarmonicDrive® with high reduction ratios, HDSI developed the HP series.

The HPG series, which is the current flagship, is the third generation series. HDSI has been evolving each of the speed reducers to meet the market demand for higher torque. At the same time, HDSI has been meeting new customer needs by developing a unique mechanism to achieve low backlash and completing a planetary speed reducer mechanism with a hollow structure which was previously difficult to achieve. The proprietary design and precision machining techniques that HDSI had been accumulating over the years have resulted in the development of speed reducers for precision control.

In the future, HDSI will continue research and development toward innovative AccuDrive® products while improving the HPG-R series developed in 2020.

# Chronology of Technology

- HarmonicDrive® products
- Mechatronics products
- AccuDrive® (planetary gear) products

Year	Technology Overview/Product Overview/Product Introduced to the Market
1955	Filed a patent for the invention of strain wave gearing (hereafter called HarmonicDrive®).
1959	Registered a patent for HarmonicDrive®.
1960	An American mechanical engineering magazine <i>Machine Design</i> carried an article on HarmonicDrive®.
1964	Hasegawa Gear Works was granted a license for the technology introduction agreement for HarmonicDrive®. ● Succeeded in prototyping HarmonicDrive®.
1965	● Started standardizing HarmonicDrive® into 8 sizes of Sizes 20 to 100 and 8 models. ● Delivered the first domestically produced HarmonicDrive®. ● Filed a patent for the invention of Shifted HarmonicDrive®.
1966	● Introduced the HarmonicDrive® Component Type 2 and 2A (semi-standard) in 8 sizes of Standard Sizes 20 to 100 to the market. ● Introduced the HARMONIC MOTOR® Types 3 and 4 with induction motor to the market. ● Introduced the HarmonicDrive® Types 0, 0A, 1, and 1A with input/output shaft to the market. ● Introduced the large sizes of Sizes 130, 160, and 200 to the market. ● Started manufacturing the Harmonic Coupling (later called FineJuster®) Size 4. ● Introduced RESPONSYN to the market.
1967	● Introduced the HarmonicDrive® Type CD with double reduction and Type CG with first stage gear to the market.
1968	● Used the double eccentric wave generators for special purposes. ● Introduced the knob unit for microscopes to the market.
1969	● Signed a basic sales agreement for the shutter actuators (Sanwa Shutter Corporation).
1970	● Started developing sizes of HarmonicDrive® smaller than Size 20. ● Registered a patent for Shifted HarmonicDrive®. ● Introduced the heavy-weight shutter actuator to the market. ● Introduced the valve actuator VB series to the market.
1972	● Introduced the stainless-steel standard Type 2 component CS-14-2 to the market. ● Introduced the FineJuster® J-16 to the market. ● Introduced the low-speed flat type FH-32 to the market. ● Introduced the phase adjustment differential units FD-20, 25, 32, 40, and 50 to the market. ● Introduced the pancake type FB series FB-20, 25, and 32 to the market. ● Introduced the HarmonicDrive® with the Kopp variable speed drive to the market. ● Introduced the UHF TV antenna actuators to the market.
1973	● Introduced the HarmonicDrive® with a torque controller to the market.
1974	● Developed the Oldham-type wave generator. ● Introduced the lightweight shutter actuator SG15 to the market. ● Introduced the HarmonicDrive® with a low-speed hydraulic motor to the market. ● Started developing the special grease for HarmonicDrive®. ● Introduced the HarmonicDrive® for clarifiers to the market.
1975	● Introduced the low-speed manual input component FH-25, 32, and 40 series to the market.
1977	● Introduced the early R series of HarmonicDrive® CS-20 to 100 to the market. ● Developed the hydraulic wave generator.
1978	● Introduced the HarmonicDrive® CS-14-2A to the market. ● Imported and sold the electromagnetic HarmonicDrive® RESPONSYN HDM-15, 155, 175, and 170 as core products. ● Developed in-house the driver unit DU-200 for electromagnetic HarmonicDrive® RESPONSYN. ● Introduced the DC servo actuator Hi.T Drive HT-14, 20, and 25 to the market.
1979	● Introduced the flat type HarmonicDrive® FR series to the market. ● Introduced HT-14P and 20P, Hi.T Drive with a stepping motor, to the market.
1980	● Started investigating low reduction ratio speed reducers.
1982	● Introduced the HarmonicDrive® CS-8 and 11-2A to the market. ● Introduced the R series of HarmonicDrive® CS-20 to 100 (specifications fixed for robot applications) to the market. ● Completed the development of HarmonicGrease® SK-1 and SK-2. ● Introduced the low reduction ratio HarmonicDrive® 1/50 and 1/60 series to the market. ● Introduced the DC servo driver HS-200 series to the market.
1983	● Received an order for the development of HarmonicDrive® for Space. ● Expanded the DC servo driver series by gradually introducing the HS-300 and HS-400 series, etc. to the market. ● Introduced the RESPONSYN HDM-185 to the market. ● Developed the optical encoder ME series for DC servo actuators.
1984	● Exhibited prototypes of the unit type HarmonicDrive®. ● Introduced the DC servo actuator RA series with a shorter length in the axial direction than the HT series to the market. ● Introduced the DC servo actuator RH-20, 25, and 32 with the DC servo motor and optical encoder developed in-house to the market. ● Introduced the robot joint actuator RK-J series to the market. ● Introduced the serial pulse command DC servo driver unit HS-300 series to the market.
1985	● Introduced the smallest size of HarmonicDrive® CS-5-2A to the market. ● Introduced the HarmonicDrive® GR series with a low inertia wave generator to the market. ● Introduced the fine index $\theta$ table FIU-20 to the market.
1986	● Introduced the silk hat type HarmonicDrive® SH series to the market. ● Developed the storm line (diaphragm shape). ● Filed a patent for the IH tooth profile. ● Developed the HarmonicDrive® CS-4. ● Started considering planetary gear speed reducers. ● Started developing the AccuDrive® BP series. Entered a development and sales partnership with Machinery Engineering Corporation. ● Introduced the wheel actuator MH planetary speed reducer to the market.
1987	● Introduced the micro & supermini actuator RH-5, 8, 11, and 14 to the market.

Year	Technology Overview/Product Overview/Product Introduced to the Market
1987	● Introduced the PC command DC servo unit HS-400 series to the market. ● Introduced the AC servo actuator RS series RS-14, 20, 25, and 32 to the market. ● Introduced the stepping motor actuator RP-14 and 20 to the market. ● Started developing the flat hollow actuator FHA-25A. ● Acquired the trademark right for AccuDrive®.
1988	● Introduced the high-strength CSS series with the IH tooth profile, Sizes 20, 25, 32, 40, and 50, to the market. ● Introduced the high-strength silk hat type SHS series with the IH tooth profile to the market. ● Introduced the FRS/FDS series with the IH tooth profile, Sizes 20, 25, 32, 40, and 50, to the market. ● Completed the development of HarmonicGrease® HC-1. ● Introduced the planetary speed reducer AccuDrive® BP series with the backlash adjustment mechanism to the market.
1989	● Introduced the high-strength CSS/FRS series with the IH tooth profile, Sizes 65, 80, and 100, to the market. ● Introduced the HarmonicDrive® CS-17-2A to the market. ● Introduced the linear actuator LA-P with a pulse motor to the market. ● Introduced the flange shape output DC servo actuator RF series to the market. ● Introduced the AC servo actuator RS-8, 11, and 14 to the market. ● Introduced the DC servo actuator RHS-20, 25, and 32 to the market. ● Introduced the fine index $\theta$ table FIU-14 to 32 (including the driver UDX) to the market. ● Introduced the linear actuator LA-30 to the market. ● Introduced the stepping motor actuator RP-8 and 11 (including the driver UDX) to the market.
1990	● Introduced the high-strength CSS-50, 65, 80, and 100-2A, reduction ratio 1/50 series, to the market. ● Introduced the flat type HarmonicDrive® FB and FR-17 to the market. ● Introduced the unit type HarmonicDrive® CSS, FRS-20, 25, 32, 40, and 50-2UH to the market. ● Introduced the HarmonicDrive® CS-8 to 20, reduction ratio 1/72, to the market. ● HarmonicDrive® for Space was adopted for the Flight Telerobotic Servicer (FTS). ● Introduced the flat hollow actuator FHA-25A to the market. ● Introduced the AC servo driver HA-220 to the market. ● Introduced the wheel actuator WAC-MH to the market. ● Introduced the DC servo actuator RFS-20, 25, and 32 to the market. ● Introduced the AC servo actuator RSS-20, 25, and 32 to the market. ● Introduced the AC servo actuator RKS-20, 25, and 32 to the market. ● Introduced the DC servo driver HS series 9A specification to the market. ● Introduced the X/Y 2-axis nanometer stage XY-100-10 to the market. ● Introduced the linear actuator LA-32 (Stroke: 30mm, 50mm) to the market. ● Introduced the AccuDrive® HP-16 to 32-F to the market.
1991	● Introduced the HarmonicDrive® CSS-14, reduction ratio 1/50 and 1/80, and CSS-17, reduction ratio 1/50, to the market. ● Introduced the HarmonicDrive® medium size CSS, FRS-45, 58, 90-2A, and 2UH to the market. ● Introduced the HarmonicDrive® compact unit type CS-14 and 17-2UH to the market. ● Introduced the ultra-high vacuum rotational motion feedthrough Rotary Feedthrough HDRF-8 to the market. ● Introduced the HarmonicDrive® SH-17 to the market. ● Introduced the controller for the X/Y 2-axis nanometer stage NSC-2A to the market. ● Introduced the finite angle nanoradian stage LFI-80-6 to the market. ● Introduced the DC servo actuator RHS-14 and 17 to the market. ● Introduced the DC servo actuator RFS-14 and 17 to the market. ● Introduced the AC servo actuator RSS-14 and 17 to the market. ● Introduced the AC servo actuator RKS-14 and 17 to the market. ● Introduced the AccuDrive® HP-40, 50, and 65 to the market.
1992	● Introduced the thin HarmonicDrive® CSF-20 to 100-2A to the market. ● Introduced the thin HarmonicDrive® CSF-20 to 100-2UH/2UJ to the market. ● Completed the development of HarmonicGrease® SK-3. ● Completed the development of HarmonicGrease® SK-1A. ● Completed the development of HarmonicGrease® HC-1A. ● Started developing the cross roller bearings. ● Started the Bent Sub project. ● A satellite with the domestically produced HarmonicDrive® was launched. ● Introduced the high driving force linear actuator LAH-46 to the market. ● Introduced the flat hollow actuator FHA-40A to the market. ● Introduced the 2-axis positioning controller MC-20A to the market. ● Introduced the flat hollow actuator FHA-17A and 25B to the market.
1993	● Introduced the thin HarmonicDrive® CSF-14 and 17-2A to the market. ● Introduced the thin HarmonicDrive® CSF-14, 17-2UH, and 2UJ to the market. ● Introduced the flat hollow actuator FHA-25B and 40A-S248 with an absolute encoder to the market. ● Introduced the flat hollow motor MAA (motor unit for FHA) to the market. ● Introduced the nanometer positioner LNP-5065-10 to the market. ● Introduced the general-purpose high driving force linear actuator HDPL to the market. ● Introduced the AC servo driver HA-600 to the market. ● Introduced the AccuDrive® HP, CP-14, 16, 20, 25, 32, and 40A to the market.
1994	● Introduced the flat hollow actuator FHA-32B and 40B to the market. ● Introduced the optical Galvano scanner LSA-50A and driver PSC-20A and PSM-100 to the market. ● Introduced the linear actuator LA-30B-10-F to the market. ● Introduced the AccuDrive® HP-16B to the market.
1995	● Introduced the silk hat type HarmonicDrive® SHF-14 to 58-2A to the market. ● Introduced the silk hat type HarmonicDrive® SHF-14 to 58-2UH and 2UJ to the market.

Year	Technology Overview/Product Overview/Product Introduced to the Market
1995	<ul style="list-style-type: none"> <li>Established the manufacturing technology for cross roller bearings and achieved commercialization.</li> <li>Registered a patent for the IH tooth profile.</li> <li>Introduced the AC servo driver HA-700 to the market.</li> <li>Introduced the linear actuator LBC-25A to the market.</li> <li>Introduced the RH supermini series Type B to the market.</li> <li>Introduced the linear actuator LBN-25A to the market.</li> <li>Introduced the linear actuator (with a pulse motor) LA-30B-10-F-P to the market.</li> <li>Introduced the AccuDrive® HP and CP-50A to the market.</li> </ul>
1996	<ul style="list-style-type: none"> <li>Introduced the RH supermini series Type C to the market.</li> <li>Introduced the AC servo driver HA-750 to the market.</li> <li>Started developing direct drive motors.</li> <li>Introduced the AccuDrive® HP, CP-14, 16, 20, 25, 32, 40, and 50C to the market.</li> </ul>
1997	<ul style="list-style-type: none"> <li>Introduced the HarmonicDrive® CS-5, reduction ratio 1/50 and 1/100, to the market.</li> <li>Completed the development of HarmonicGrease® 4B-No.2.</li> <li>Introduced the flat hollow actuator FHA-50A to the market.</li> <li>Introduced the optical Galvano scanner driver PSM-100-SP to the market.</li> <li>Introduced the flat hollow actuator FHA-17A, 25B, 32B, and 40B-HC to the market.</li> <li>Introduced the flat hollow actuator FHA-14A to the market.</li> <li>Introduced the AC servo actuator RJ-16 with AccuDrive® to the market.</li> <li>Introduced the AccuDrive® HP-11F to the market.</li> </ul>
1998	<ul style="list-style-type: none"> <li>Introduced the linear actuator LAH-80 to the market.</li> </ul>
1999	<ul style="list-style-type: none"> <li>Introduced the HarmonicDrive® CSS-8, reduction ratio 1/30, to the market.</li> <li>Introduced the HarmonicDrive® CSF-8 to 17, reduction ratio 1/30, to the market.</li> <li>Introduced the HarmonicDrive® CSG-20 to 40 to the market.</li> <li>Introduced the cam type linear actuator LACH-25, 35, and 45 to the market.</li> <li>Introduced the optical Galvano scanner LSA-20A to the market.</li> <li>Introduced the HarmonicPlanetary® HPG-14A, 20A, and 32A, reduction ratio 1/5, 1/11, 1/21, and 1/33, to the market.</li> </ul>
2000	<ul style="list-style-type: none"> <li>Commercialized the HarmonicDrive® unit with a torque sensor.</li> <li>Introduced the HarmonicDrive® CSF-8 and 11, reduction ratio 1/50, 1/80, and 1/100, Type 2A to the market.</li> <li>Introduced the HarmonicDrive® CSF-20 to 32-2A and 2UH, reduction ratio 1/30, to the market.</li> <li>Introduced the DC servo driver HS-360 to the market.</li> <li>Introduced the flat hollow actuator FHA-17C, 25C, and 40C to the market.</li> <li>Introduced the AC servo driver HA-650/670 to the market.</li> <li>Acquired the trademark right for HarmonicPlanetary®.</li> </ul>
2001	<ul style="list-style-type: none"> <li>Introduced the super flat HarmonicDrive® CSD-20 to 50-2A to the market.</li> <li>Introduced the flat hollow actuator FHA-32C to the market.</li> <li>Introduced the RH supermini series Type D to the market.</li> <li>Introduced the absolute angle sensor system MIT series to the market.</li> <li>Introduced the auto centering system ACS series to the market.</li> <li>The HarmonicPlanetary® HPG was awarded the JSPE Technology Award.</li> </ul>
2002	<ul style="list-style-type: none"> <li>Introduced the HarmonicDrive® CSF-5 to 14-1U, 2XH, and 2XJ to the market.</li> <li>Introduced the 8-inch HarmonicDrive® for bent subs to the market.</li> <li>Introduced the 12-inch HarmonicDrive® for bent subs to the market.</li> <li>Introduced VF-17-50-S1 for in-vehicle applications to the market.</li> <li>Introduced the HarmonicDrive® CSG-14 to 40-2A and 2UH with improvements to the market.</li> <li>Introduced the HarmonicDrive® SHG-14 to 40-2A, 2UH, and 2UJ to the market.</li> <li>Introduced the silk hat type HarmonicDrive® SHF-14 to 32, reduction ratio 1/30, to the market.</li> <li>Introduced the flat hollow actuator FHA-17C to 40C-S248 to the market.</li> <li>Introduced the AC servo driver HA-655-2 and 4 to the market.</li> <li>Introduced the AC servo driver HA-675-2 and 4 to the market.</li> <li>Introduced the optical Galvano scanner LSA-20B (-D-K1, K2) and driver PSM-120 to the market.</li> <li>Introduced the micro encoder MES series to the market.</li> <li>Introduced the HarmonicPlanetary® HPG-50A to the market.</li> <li>Introduced the HarmonicPlanetary® HPG-20A and 32A with a backlash specification of 1 arc-min or less to the market.</li> </ul>
2003	<ul style="list-style-type: none"> <li>Introduced the HarmonicDrive® CSF-14, 20, 32, 45, and 65-GH to the market.</li> <li>Introduced the HarmonicDrive® CSG-45 to 65 to the market.</li> <li>Introduced the HarmonicDrive® SHG-45 to 65 to the market.</li> <li>Introduced the super flat HarmonicDrive® CSD-14 and 17-2A to the market.</li> <li>Introduced the super flat HarmonicDrive® SHD-14 to 40-2UH (including 2A) to the market.</li> <li>Introduced the AC servo actuator RSF-8A, 11A, and 14A to the market.</li> <li>Introduced the AC servo actuator RSF-17A, 20A, 25A, and 32A to the market.</li> <li>Introduced the AC servo driver HA-520 to the market.</li> <li>Introduced the AC servo actuator RKF-20A, 25A, and 32A to the market.</li> <li>Introduced the stepping motor actuator RP-11B, 14B, and 20B to the market.</li> <li>Introduced the flat hollow actuator FHA-8C, 11C, and 14C to the market.</li> <li>Introduced the AC servo driver HA-655-1 to the market.</li> <li>Introduced the AC servo driver HA-675-1 to the market.</li> <li>Introduced the flat hollow actuator FHA-17C to 40C-D250, and US250 (14-wire) to the market.</li> <li>Introduced the HarmonicPlanetary® HPG-14A with a backlash specification of 1 arc-min or less to the market.</li> <li>Introduced the AccuDrive® HP-8F to the market.</li> </ul>

Year	Technology Overview/Product Overview/Product Introduced to the Market
2004	<ul style="list-style-type: none"> <li>Introduced the flat hollow actuator FHA-8C, 11C, 14C-E, and -E-SP (24V) to the market.</li> <li>Introduced the flat hollow actuator FHA-8C, 11C, 14C-D200, and US200 (14-wire) to the market.</li> <li>Introduced the AC servo driver HA-680 to the market.</li> <li>Introduced the driver PSM-130 for the optical Galvano scanner LSA-10A to the market.</li> <li>Introduced the HarmonicPlanetary® HPG-U1 to the market.</li> <li>The HarmonicPlanetary® HPG series was awarded a Good Design Award.</li> </ul>
2005	<ul style="list-style-type: none"> <li>Introduced VC-32-200-S1 for in-vehicle applications to the market.</li> <li>Introduced the AC servo actuator RSF-5A and 5B to the market.</li> <li>Introduced the HarmonicPlanetary® HPG-11A and B to the market.</li> <li>Introduced the HarmonicPlanetary® HPG-65A (except for -RA orthogonal shaft) to the market.</li> <li>Introduced the LCD drive unit HP-11F-2100-SUM to the market.</li> </ul>
2006	<ul style="list-style-type: none"> <li>Introduced the HarmonicDrive® CSF-3 and 3B to the market.</li> <li>Introduced VF-17-50-S2 for in-vehicle applications to the market.</li> <li>Introduced new models of the HarmonicDrive® CSF-5 to 14-1U, 2XH, and 2XJ to the market.</li> <li>Introduced VF-14-85-S1 for in-vehicle applications to the market.</li> <li>Introduced VC-25-200-S1 for in-vehicle applications to the market.</li> <li>Introduced the AC servo actuator RSF-3A, 3B, and 3C to the market.</li> <li>Introduced the direct drive motor KDU-13 to the market.</li> <li>Introduced the lens drive linear motor PSM-125 to the market.</li> <li>Introduced the driver supporting communication protocols HA-800/680 to the market.</li> <li>Introduced the HarmonicPlanetary® HPG-14A to 50A-3 to the market.</li> </ul>
2007	<ul style="list-style-type: none"> <li>Introduced the AC servo driver HA-680 ML (MECHATROLINK) to the market.</li> <li>Introduced the AC servo driver HA-680 CL (CC-Link) to the market.</li> <li>Introduced the AC servo actuator RSF-8B, 11B, and 14B to the market.</li> <li>Introduced the HarmonicPlanetary® HPG-32, 50, 52, and 65A-RA orthogonal shaft to the market.</li> </ul>
2008	<ul style="list-style-type: none"> <li>Introduced the super flat HarmonicDrive® CSD-2UH and 2UF to the market.</li> <li>HarmonicDrive® for Space SHF and CSD were registered as JAXA's component parts.</li> <li>Introduced the AC servo driver HA-800-1, 3, and 6 (medium capacity) to the market.</li> </ul>
2009	<ul style="list-style-type: none"> <li>Introduced the flat hollow actuator SHA-25, 32, 40, 58, and 65 to the market.</li> </ul>
2010	<ul style="list-style-type: none"> <li>Introduced the AC servo driver HA-800-24 (high capacity) to the market.</li> <li>Introduced the flat hollow actuator SHA-25P, 32P, 40P, 58P, and 65P compatible with Panasonic's format to the market.</li> </ul>
2011	<ul style="list-style-type: none"> <li>Introduced the silk hat type HarmonicDrive® SHF-11 to the market.</li> <li>Introduced the flat hollow actuator SHA-25 and 32 with a hollow planetary speed reducer to the market.</li> <li>Introduced the HarmonicPlanetary® flat hollow planetary HPF to the market.</li> </ul>
2012	<ul style="list-style-type: none"> <li>Introduced the HarmonicDrive® CSF-17-GH to the market.</li> <li>Introduced the HarmonicDrive® CSG-GH to the market.</li> <li>Introduced the lightweight HarmonicDrive® CSF and CSG-2UH-LW to the market.</li> <li>Introduced the lightweight HarmonicDrive® SHF and SHG-2UH-LW to the market.</li> <li>Introduced the lightweight HarmonicDrive® SHD-2UH-LW to the market.</li> <li>Introduced the AC servo driver HA-690 to the market.</li> <li>Introduced the changes of the encoder communication protocol to the other servo motor manufacture's specification to the market.</li> <li>Introduced the HarmonicPlanetary® high torque HPGP series to the market.</li> </ul>
2013	<ul style="list-style-type: none"> <li>Introduced the flat hollow actuator SHA-25M, 32M, 40M, 58M, and 65M for the collaboration with Mitsubishi Electric to the market.</li> <li>Introduced the flat hollow actuator SHA-20 to the market.</li> <li>Introduced the HarmonicPlanetary® HPN-14A, 20A, and 32A to the market.</li> </ul>
2014	<ul style="list-style-type: none"> <li>Introduced the HarmonicDrive® CSG-2UK to the market.</li> <li>Introduced the flat hollow actuator SHA-25, 32, 40, 58, and 65-CG (KHA) to the market.</li> <li>Introduced the HarmonicPlanetary® HPN-11A and 40A to the market.</li> </ul>
2015	<ul style="list-style-type: none"> <li>Introduced the HarmonicDrive® CSF-2UP to the market.</li> <li>Introduced the flat hollow actuator SHA series for the collaboration with YASKAWA Electric to the market.</li> <li>Introduced the high-precision flat hollow actuator FHA-C-PR to the market.</li> <li>Introduced the HarmonicPlanetary® HPG-R helical single-stage (low reduction ratio) to the market.</li> </ul>
2016	<ul style="list-style-type: none"> <li>Introduced FRS-25 for in-vehicle VCT to the market.</li> <li>Introduced the flat hollow actuator FHA-8C, 11C, and 14C for the collaboration with Mitsubishi Electric to the market.</li> <li>Introduced the AC servo actuator RSF-3C and 5B for the collaboration with Mitsubishi Electric to the market.</li> </ul>
2017	<ul style="list-style-type: none"> <li>Introduced the additional reduction ratios of the super flat HarmonicDrive® CSD and SHD series to the market.</li> <li>Introduced the flat hollow actuator SHA-20P for the collaboration with Panasonic to the market.</li> <li>Introduced the additional reduction ratios for HarmonicPlanetary® HPN series with the double-stage gear to the market.</li> </ul>
2018	<ul style="list-style-type: none"> <li>Completed the development of HarmonicGrease® HFL-1 for the food industry.</li> <li>Introduced the super flat brushless DC actuator FLA-14, 17, and 20 to the market.</li> <li>Introduced the flat hollow actuator FHA-C, reduction ratio 80 and 120, to the market.</li> <li>Introduced the flat hollow motor HMA (motor unit for SHA) to the market.</li> <li>Introduced the flat hollow motor HMA for the collaboration with Mitsubishi Electric to the market.</li> <li>Introduced the HarmonicPlanetary® HPN-L (face mounting, for North America) to the market.</li> </ul>
2019	<ul style="list-style-type: none"> <li>Introduced the large hollow flat FBS unit for robots to the market.</li> <li>Introduced the flat hollow motor HMA for the collaboration with YASKAWA Electric to the market.</li> <li>Introduced the flat hollow motor HMA for the collaboration with Panasonic to the market.</li> <li>Introduced the flat hollow actuator SHA-45 to the market.</li> <li>Introduced the HarmonicPlanetary® HPN series orthogonal shaft type to the market.</li> </ul>
2020	<ul style="list-style-type: none"> <li>Introduced the ultra-lightweight flat HarmonicDrive® unit CSF and CSD-ULW series to the market.</li> <li>Introduced the HarmonicPlanetary® HPG helical double-stage to the market.</li> </ul>

# Applications

**1** Space industry  
(Lunar rover)



**2** Space industry  
(Mars rover)



Rover image created by Dan Maas, copyright and provided courtesy NASA/JPL-Caltech

**3** Space industry  
(Hayabusa; Hayabusa 2)



Photo courtesy of JAXA

**4** Large-scale optical/  
Infrared telescope  
"Subaru" on Mauna Kea  
in Hawaii



Photo courtesy of the National  
Astronomical Observatory of  
Japan

**5** Semiconductor wafer  
transport robots



Photo courtesy of Daihen  
Corporation

**6** Industrial robots



(for illustration purposes only)

**7** Mobility vehicles



Photo courtesy of Toyota Motor  
Corporation

**9** Flying cars



(for illustration purposes only)

**10** Drill steering systems  
for oil and gas industries



Courtesy of Halliburton/ Sperry Drilling  
Services

**11** Co-bots



Photo courtesy of Techman Robot Inc.

**12** Surgical robots



(for illustration purposes only)

**13** Small robot finger module



Photo courtesy of Ishikawa Group Laboratory  
of the University of Tokyo

**14** Humanoid robots

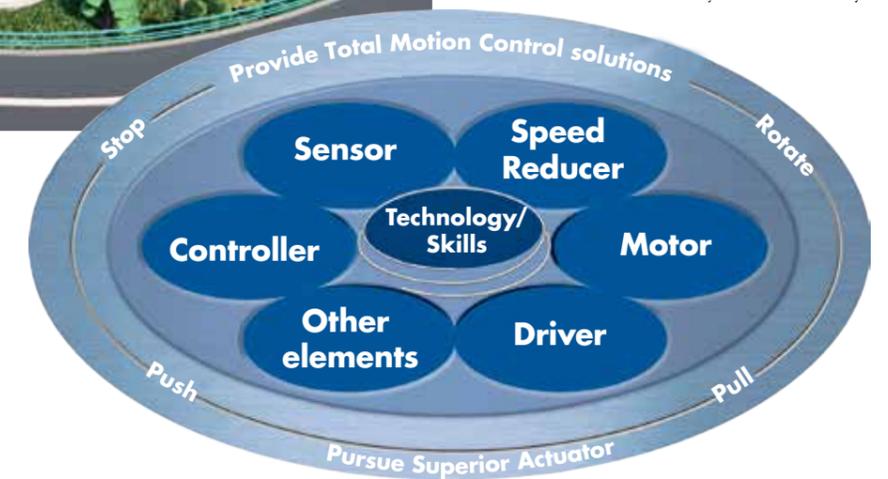


Photo courtesy of Honda  
Motor Co., Ltd.

**15** Power assist suits



Photo courtesy of Hashimoto  
Laboratory of Shinshu University



## Technology-Related Commendations and Awards

Date	Received Commendations and Awards	Awarding Organization	Description
2001	JSPE Technology Award	The Japan Society for Precision Engineering	Development of a high-performance planetary gear mechanism with minimal backlash
2003	The Massillon Plaque Company 2003 R&D100 Awards Winners	Toyota Motor Corporation	VGRS Variable Gear Ratio Steering System (Mechanical Devices) Primary Developer: Toyota Motor Co. Codevelopers: Harmonic Drive Systems Inc., Toyoda Machine Works, Ltd.
2004	Good Design Award 2004	Japan Institute of Design Promotion	HarmonicPlanetary® HPG Series high-performance gear head for planetary gear reducers and servo motors (Harmonic AD, Inc.) Product Design Award, division of machine tools, industrial machinery, transport equipment and vehicles, test equipment
September 16, 2004	JSPE Takagi Award	The Japan Society for Precision Engineering	Research on the angular standard and traceability of rotary encoders
February 24, 2006	Technology development prize	Toyota Motor Corporation	Electric active stabilizer system jointly developed with Chuo Spring Co., Ltd. and Aisin Seiki Co., Ltd.
September 20, 2006	JSME Excellent Product Award	The Japan Society of Mechanical Engineers	New HarmonicDrive® SHF series and SHG series For contributions to the development of mechanical engineering and machine technology with superior technology highly acclaimed in society and industry
May 26, 2007	Best Paper Award	The Japan Society for Design Engineering	Recipients: Hiroshi Yamazaki, Satoshi Kishi, Yoshitaroh Yoshida, Tomio Horiuchi, Yoshihide Kiyosawa, and Shinji Kasei "A Study of Designing and Manufacturing Method of Pinion Cutter for Non-involute Internal Gear"
December 20, 2007	Robot Awards, Ministry of Economy, Trade and Industry (METI) Top robot component selected by Organization for Small and Medium Enterprises and Regional Innovation (SMRJ)	The Ministry of Economy, Trade and Industry	Ultra-small, high-precision, high-output-torque AC servo actuator
December 20, 2007	Robot Awards, Ministry of Economy, Trade and Industry (METI) Excellence award, robot components and software	The Ministry of Economy, Trade and Industry	Ultra-small, high-precision, high-output-torque AC servo actuator
June 6, 2008	Outstanding Scientific Achievement Award, Robotics and Mechatronics Division	The Japan Society of Mechanical Engineers	For technological contributions to the development of robotics and mechatronics
May 28, 2016	Award for Meritorious Achievement	The Japan Society for Design Engineering	Recipient: Shoichi Ishikawa For his contribution to the realization of humanoid robots, etc. by achieving practical utilization and improved performance of the HarmonicDrive® speed reducers
March 9, 2017	Contribution Award	Hokuriku-Shinetsu Branch of the Japan Society of Mechanical Engineers	Recipient: Yoshihide Kiyosawa For his years of contribution to the development of the Hokuriku-Shinetsu Branch
February 15, 2018	Certificate of Appreciation	Nissan Motor Co., Ltd.	For the achievement of the goal of developing HarmonicDrive® for the new QX50
July 2018	Nissan Global Supplier Award - Global Innovation Award	Nissan Motor Co., Ltd.	
September 6, 2018	JSPE Technology Award	The Japan Society for Precision Engineering	For research and product development related to the designing of high-speed high-precision control systems for positioning mechanisms incorporating strain wave gearing
November 9, 2018	Academic Experts Award of Merit Celebrating the 80th Anniversary of the Japan Gear Manufacturers Association	The Japan Gear Manufacturers Association	Recipient: Shoichi Ishikawa For his years of contribution to research on gears
March 18, 2020	Certificate of Appreciation	The Japan Society for Precision Engineering	For the cooperation with the Society as a Corporate Member over the years

## Editorial Note to the Technological History

We are pleased to publish the Technological History along with the Fifty-Year History, which we have been compiling as part of the project celebrating the 50th anniversary.

We hope the technological history will serve as a guidebook for employees who carry the future of HDSI. We described the development and expansion of the HarmonicDrive® speed reducers with behind-the-scenes stories about the development so that it could be used as materials on the industrial history.

We hope this enlightens you on the history of how this mechanism invented by C. Walton Musser became widely used for precision positioning mechanisms in the industry after HDSI's repeated efforts for development, commercialization, and market introduction.

Lastly, I would like to take this opportunity to express my gratitude to Advisor Sasahara, officers, employees, and alumni, who helped us in the compilation, and the members of the Compilation Room who did their best to complete the technological history.

Hiroshi Ozawa  
Director of the Company History Compilation Room

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