THE CANON FRONTIER 2018/2019

Focus on Technology and R&D

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About the Cover

Canon's FPA-1200NZ2C nanoimprint semiconductor lithography equipment in use at Toshiba Memory's Yokkaichi Operations plant, Japan. (see P.23)

Chapter 1

Inspiring Innovation

**An emphasis on technology is part of Canon's corporate DNA.
With this in mind, we are setting our sights on utilizing our imaging technologies, which go beyond our rich lineup of products, to "archive" the world and, with our ambitions extending even further beyond that, space.
By constantly tackling new challenges, we firmly believe that we can uphold our philosophy of "Kyosei"—all people, regardless of race, religion or culture, harmoniously living and working together into the future—and contribute to a prosperous society.**

Technologies Supporting Canon

Innovative Technologies that Support Lifestyles, Business and Industry

Professional


Professional digital SLR cameras


Digital cinema cameras


Ophthalmic equipment


X-ray angiography systems


X-ray CT diagnostic systems


Broadcast equipment


Digital radiography


Professional digital video camcorders


Diagnostic ultrasound systems


MRI systems


Interchangeable lenses


Professional displays


Professional inkjet printers

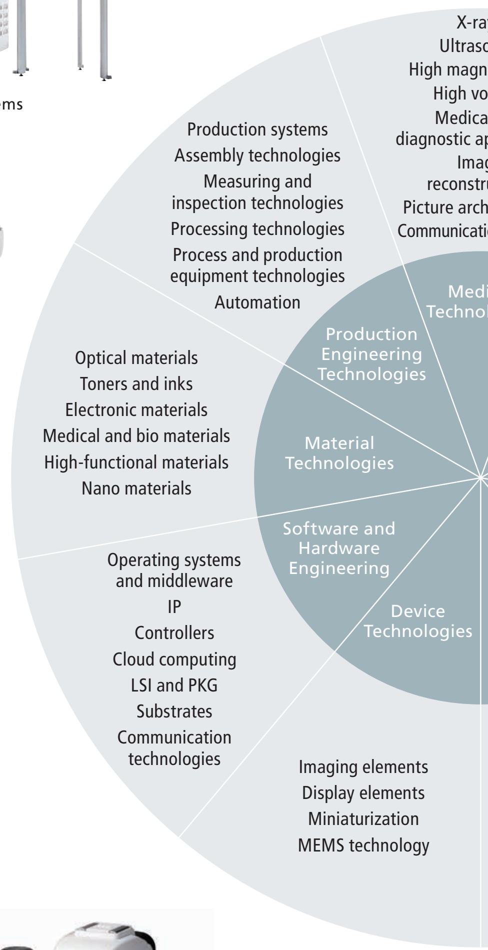



Image scanners


Digital compact cameras

Home


Compact photo printers

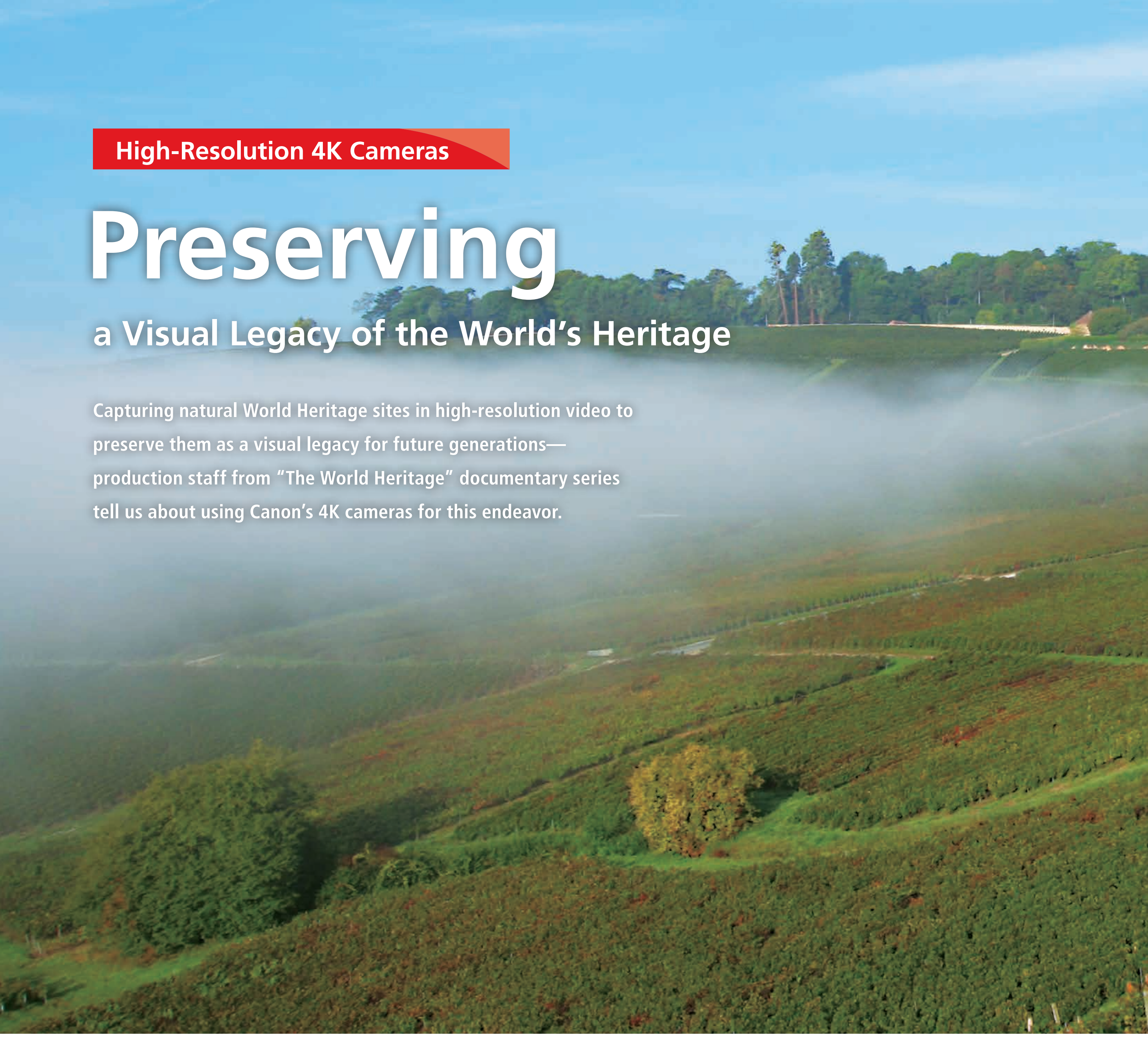

Mirrorless cameras


Digital SLR cameras


Inkjet printers


Digital video camcorders

Over the course of Canon's more than 80 year history, prioritizing technology has been a part of Canon's corporate DNA and represents the source of Canon's innovative technologies. The unique core technologies that the company has cultivated over the years have led to the creation of nine fields of R&D, which include optical technologies and image communication technologies. The company is engaged in business activities for products and services in four major areas of use: Professional, Home, Office and Industry. With the aim of developing new, one-of-a-kind technologies and products, Canon combines the creativity of its engineers with the company's core technologies to create never-before-seen value.



High-Resolution 4K Cameras

Preserving
a Visual Legacy of the World's Heritage

Capturing natural World Heritage sites in high-resolution video to preserve them as a visual legacy for future generations—production staff from "The World Heritage" documentary series tell us about using Canon's 4K cameras for this endeavor.

Filming Select World Heritage Sites in 4K

"The World Heritage" is a popular television program produced by TBS (Tokyo Broadcasting System Television, Inc.) that has documented hundreds of sites around the world considered precious to all of humanity. "Our approach has been to use the highest standard of video technology available to record these World Heritage sites for posterity," says 4K Special Series Producer Naohiko Ogawa. "Our efforts are aimed at preserving a visual legacy for future generations."

Extra time is put into the high-resolution video production of the series' 4K specials, aired four times a year. The World Heritage sites are carefully selected, filmed entirely using 4K cameras and then the footage is converted into full HD for terrestrial digital broadcasting. One of those specials was "The Hills that Produce the World's Best Champagne—Champagne Hillsides, Houses and Cellars," which aired on December 10, 2017.

The region of Champagne is where production of the fizzy drink was first established—from grape cultivation and fermentation to distribution. UNESCO recognized the cultural and historical value of champagne as a celebratory drink worldwide with the designation of the region as a World Heritage site in 2015. "I wanted to film the beautiful hills of the Champagne region and the delicate bubbles of champagne. That is how this project got started," reflected Director Ryo Taguchi.

The team visited France in September, the grape harvesting season, bringing with them four 4K Canon cameras equipped with the latest technology, including the EOS C700 and the EOS C300 Mark II. They went to the village of Hautvillers, the birthplace of champagne, and to the town of Epernay, with its many champagne houses. They filmed historic vineyards, production methods that haven't changed in 300 years and other facets of the champagne production process in 4K to tell the story of how this drink spread around the world as the drink of choice for a celebratory toast.

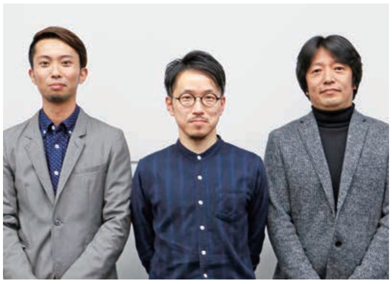
The EOS C700, used as the main camera

Champagne, France—the hillside village of Hautvillers is a World Heritage site, where the monk Dom Pérignon created the sparkling champagne wine.

Producing More Beautiful, Impressive Imagery

Currently, the 4K specials are recorded in Canon's proprietary Canon Log format. According to Taguchi, "When shooting with an ordinary format, if you try to bring out the detail of clouds in a bright sky, the fields below that are in shadow will be 'blacked out.' In contrast, if you try to bring out the detail in a dark area, the bright area will get 'whited out.' But with this format, color grading can be performed on the recorded data afterwards, and you can bring out both lights and darks well. Effectively, this means you can take each scene and bring out the full reality of it, and create a sense of being right there, with more beautiful, impressive visuals."

The recording format was not the only Canon technology that supported the filming in Champagne. As Videographer Yuki Muroya describes it, "Shooting within a dark curve, we were able to raise the ISO sensitivity higher than usual. This would normally increase the possibility of noise, but the EOS C700 is good with dark areas, so I was able to clearly show the texture of a stone wall, for example, or the gradations of other dark areas." Additionally, to shoot champagne bubbles, one of the production's key visuals, the Canon EF 180 mm f/3.5L Macro USM fixed-focal-length lens was used. Muroya adds, "That allowed me to capture the motion of the bubbles in a striking way as they rose up from the bottom of the glass. With the availability of so many interchangeable lenses, I could choose the best lens for each scene and, using them in combination with the EOS C700, really raise the quality of the images."



Yuki Muroya (left)
Videographer
Coverage Technology Department
TBS-TEX

Ryo Taguchi (center)
Director
Media Business Division,
TBS Vision

Naohiko Ogawa (right)
Deputy Director-General,
Media Business Division (4K Special Series Producer)
TBS Vision

TBS "The World Heritage"
Airing weekly on Sunday evenings at 18:00 on all TBS affiliates

The Tsuzuri Project

Perpetuating

the Art of Antiquity for Prosperity

The Tsuzuri Project is an initiative that marries Canon's latest digital technologies with traditional artisanal work to replicate precious works of Japanese art that are rarely seen by the public. By creating high-resolution facsimiles, these rare cultural assets can be shown to a wider public, perpetuating the art of antiquity for prosperity.

High-resolution facsimile of "Tigers in Bamboo Grove" by Kano Sanraku/Sansetsu from sliding door at Tenkyuin Temple.
The original is deposited at the Kyoto National Museum.

Making High-resolution Facsimiles Substantially Identical to Originals Widely Available for Public Viewing

The Tsuzuri Project was launched by Canon and the Kyoto Culture Association (NPO) in 2007 to create high-resolution facsimiles of precious Japanese cultural assets rarely shown to the public using the latest digital technologies in combination with traditional artisanal work for wider public viewing. A high-resolution reproduction is created by first photographing the work of art using Canon's latest digital SLR camera. The image data that is captured then undergoes Canon's proprietary color correction and the processed image is printed in its original size using a Canon image PROGRAF large-format inkjet printer. Master Kyoto artisans add various finishing touches as necessary, such as applying gold leaf and mounting the work.

Japan has numerous valuable cultural assets made of vulnerable materials such as paper, wood, lacquer, etc. These works of art are fragile and easily damaged. While it is necessary to offer opportunities for the public to view such works of historical and scholarly value, the works must also be protected from deterioration. In the Tsuzuri Project, 35 works have been created to date (as of December 2017), including many valuable paintings that exist on folding screens and sliding screens, and the reproductions have been made available for public viewing. These include many national treasures, such as "The Wind and Thunder Gods" by Tawaraya Sotatsu and "The Three Portraits of the Jingoji Temple," attributed to Fujiwara no Takanobu. In 2017, the Tokyo National Museum featured a high-resolution video installation that included reproductions of "Pine Trees" by Hasegawa Tohaku and "Cranes" by Ogata Korin, the latter from the collection of the Freer Gallery of Art in Washington D.C. This new style of exhibition holds great promise for allowing more people to appreciate classic works of Japanese art.

Production Process

1. Input

Segmented capturing of high-resolution data of a precious cultural asset

2. Color Matching

Output on-site and color matched with the original

3. Output

Output by using world-class printing technology employed to reproduce fine textures

4. Gold Leaf, Gold Paint and Mica

Colors degraded over time are reproduced through traditional craft techniques

5. Mounting

Mounting reproduces time-honored technique of Kyoto master craftsman

Scan to access a special video and learn more about the Tsuzuri Project.

Exhibition of "Pine Trees" by Hasegawa Tohaku (high-resolution facsimile)

A New Experience of Japanese Art: "Diving into Screen Paintings (*Byobu to Asobu*)"

An experiential art installation held in 2017 at the Tokyo National Museum's Family Gallery, "Diving into Screen Paintings (*Byobu to Asobu*)" featured a fusion of video and the reproductions of "Pine Trees" and "Cranes" from the Tsuzuri Project. Visitors sat on a tatami mat platform and were treated to an immersive video enhancement projected onto a semicircular screen behind the "Pine Trees" work, experiencing as if they were in an actual pine grove with special effects added such as music, breezes, and aromas. For the "Cranes" installation, the "dancing" of the cranes was synched to the movements of people in the audience for a mysteriously interactive exhibition.

Helping to Solve the Mysteries of the Universe

Exploring
the Origins of the Universe

Canon's core strength in optical and imaging technologies is also contributing to advances in astronomy. Canon has been involved in the Thirty Meter Telescope (TMT) project to build an extremely large 30-meter-diameter telescope in Hawaii, and has been working independently to develop an immersion diffraction element that will reduce the size of infrared spectrometers used in astronomical telescopes.

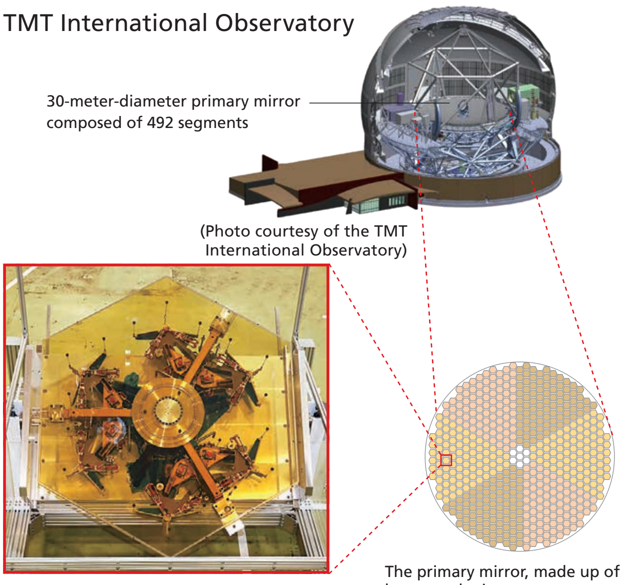
[TMT]

Important Work on a International Collaborative Project

The TMT is a five-nation international collaborative project supported by Japan, the United States, Canada, China and India to construct a huge, 30-meter-diameter telescope in Hawaii. Canon's proven track record in the development and manufacture of optics for the Subaru Telescope, National Astronomical Observatory of Japan, located at Mauna Kea, Hawaii, earned the company a role in manufacturing the mirror segments for the TMT. The TMT's 30-meter-diameter primary mirror will comprise an array of 492 segments. Different segments (a total of 574 segments when including replacement segments) will be fabricated separately in Japan, the United States, China and India. Japan is responsible for the production of approximately 30% of the mirror segments. Canon began manufacturing mirror segments in 2014, taking charge of such work as grinding and polishing the mirror surfaces, and assembling the segmented mirror units.

The hexagonal segments, made of ultra-low-expansion glass, each measure 1.44 meters diagonally and have a thickness of 45 millimeters. The mirror surface has a maximum asphericity of 0.2 millimeters, requiring a level of precision of less than 2 microns peak-to-valley. Canon developed a proprietary processing and measurement system for large aspherical mirrors that is being used to mass produce the mirror segments.

TMT International Observatory



(Photo courtesy of the TMT International Observatory)

Prototype of the TMT's segmented mirror unit

The primary mirror, made up of hexagonal mirror segments

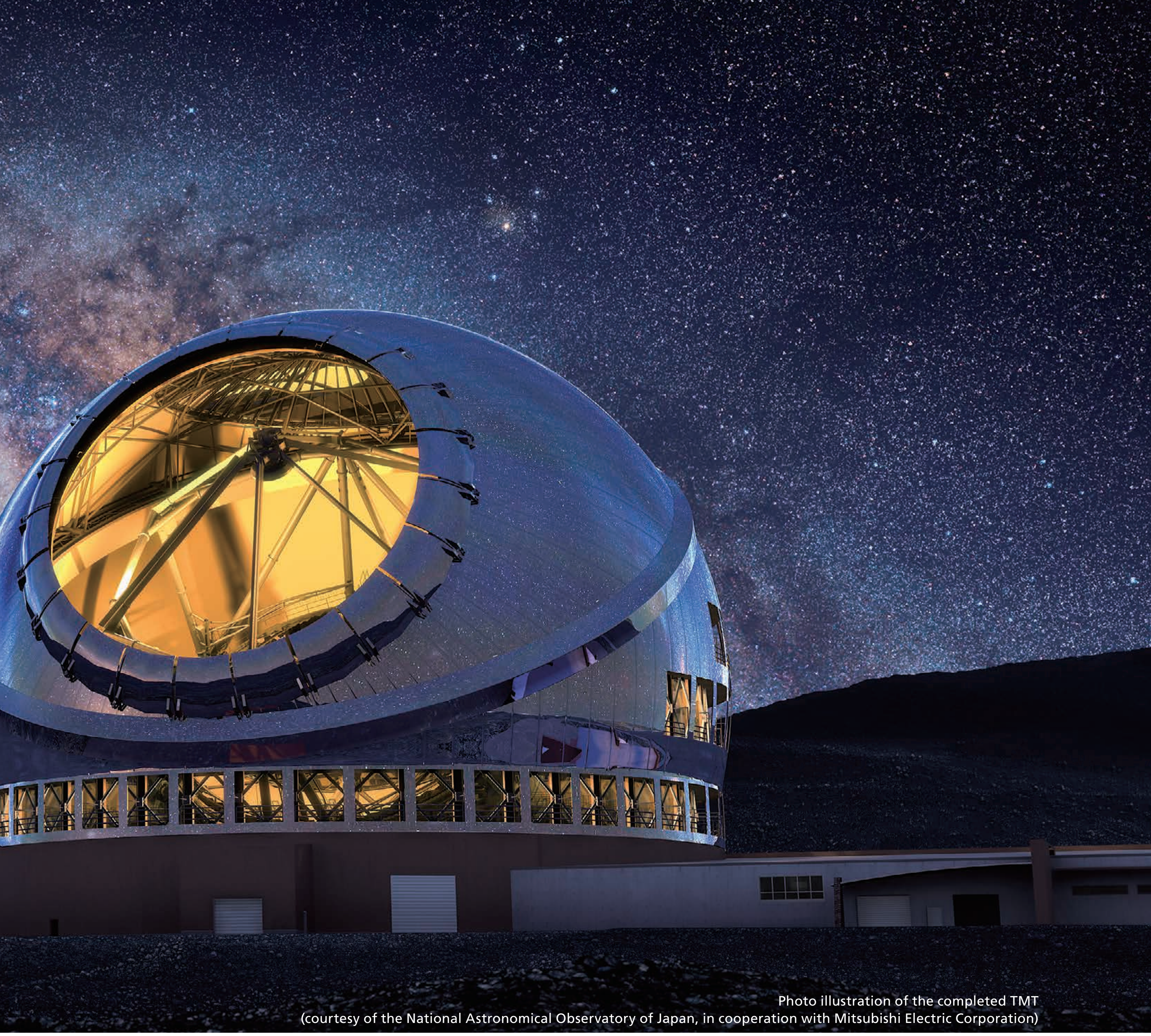


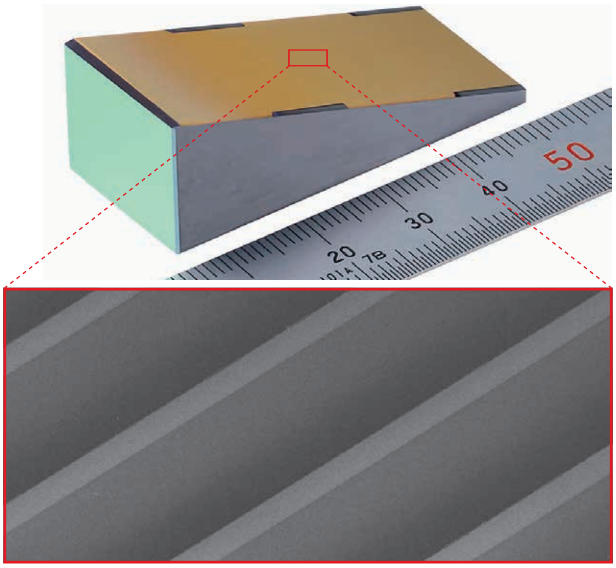
Photo illustration of the completed TMT
(courtesy of the National Astronomical Observatory of Japan, in cooperation with Mitsubishi Electric Corporation)

[Infrared Immersion Gratings]

Higher-Performance Infrared Spectrometers Could Support Investigation into the History of the Universe

In case of observing with an astronomical telescope in the space, a reflection grating has been used for a spectroscope that divides light for every wavelength in order to take out information. Canon has succeeded in developing three types—made of Germanium, Cadmium Zinc Telluride, and Indium Phosphide. These three types enable the separation of light into its spectral components, covering nearly all infrared wavelength regions. In the case of Indium Phosphide, the volume of spectrometer could reduce to about 1/27th compared with a case of conventional reflective grating with the same spectral resolution. According this effect, a space telescope which have various limitations of size and weight will be loaded with a high-performance spectroscopy. With the realization of practical immersion grating not available in the past, expectations are growing for improved light observation and control application in a wide range fields not only astronomy and aerospace but physics, chemistry and biology.

Indium Phosphide immersion diffraction element
(approx. 50 mm (l) x 20 mm (w) x 15 mm (h))



View of grading surface seen through an election microscope at 1,000x magnification

Satellite Development

Reaching Space

The Canon Group is fully utilizing its technological capabilities to push the envelope of development with Canon Electronics Inc.'s entry into the micro satellite industry.
High-resolution images taken by one such satellite are already reaching Earth.

Image of the Phoenix Sky Harbor International Airport in Arizona, U.S.A. taken by the CE-SAT-I satellite

Toward the Next Frontier

June 23, 2017—A rocket was launched into orbit from a space center in southern India, carrying the CE-SAT-I (Canon Electronics Satellite I). The micro satellite entered space 17 minutes and one second after liftoff, successfully reaching its scheduled orbit. This tiny satellite, measuring just 500 mm x 500 mm x 850 mm, is a major step forward for Canon Electronics.

The endeavor began with an order from the top: "In the future, a top company will be one that can master space. Let's be a trail-blazer and give young people new hopes and dreams." This surprise declaration from Hisashi Sakamaki, President & CEO of Canon Electronics Inc. was made in 2009. Sakamaki also set a target, "in 2030, we will achieve sales of 100 billion yen from our space business."

The Canon Electronics Inc. Future Technology Laboratory, currently in charge of the effort, is led by Senior Managing Executive Officer & Group Executive Tsumori Sato, who says he was initially quite surprised by the President's declaration. However, Canon Electronics already had the technological foundations needed to develop a micro satellite—the motor technologies for attitude control of the satellite, lens technology ranging from macro to zoom shooting and miniaturization technologies for eliminating wasted space. In addition, Canon Electronics could leverage the electronic, mechanical, optical, materials and other technologies of the Canon Group to make the satellite development possible.

The result was the CE-SAT-I. In a small chassis, the company fit a single-lens reflex camera with a catadioptric optical system, a compact camera for wide-angle image capture, and other features. Using the digital single-lens reflex camera, the imaging system could provide a 0.9 m ground resolution from a 500 km orbit within a 5 km x 3 km frame size, capable of identifying individual cars on a road. The compact camera could take wide-angle shots within a 740 km x 560 km frame.

Space: A Different Environment

Canon Electronics had confidence in its manufacturing capabilities, but developing a micro satellite was no easy task. Ground and space are two entirely different environments. "We had real difficulties in three technical areas," says Nobutada Sako, Group Executive, Satellite Systems Laboratory, Canon Electronics Inc. "One was the absence of gravity; two was the vacuum environment; and three was the unrelenting radiation in space."

The vacuum and radiation challenges were particularly difficult to overcome. Since there is no air in a vacuum, a fan will not create convection even if it turns. That means the heat generated by a CPU or other unit cannot be dissipated, and the system will shut down when the CPU overheats. The problem was eventually solved by devising a clever radiative cooling method that used metal to conduct heat away from where it was generated.

Radiation presents the danger of causing a system stoppage or malfunction. If radiation gets into the CPU, the data being written might be altered, causing an error. The development team solved the problem by testing a large number of semiconductor chips, and eventually found a moderately priced, commercially available chip that was radiation resistant.

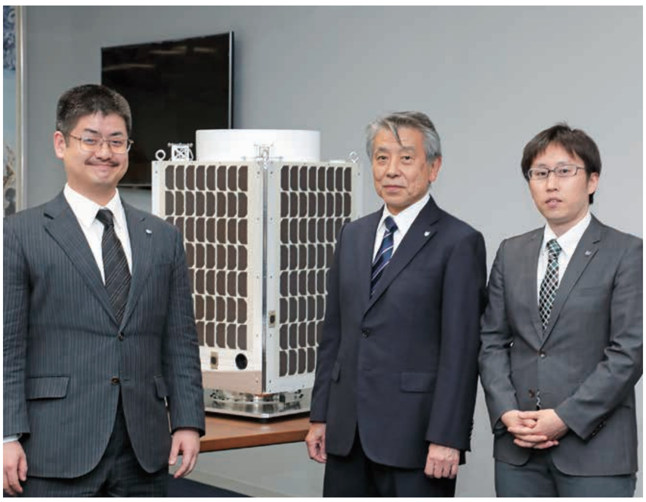
The further miniaturized CE-SAT-III measures 100 mm x 100 mm x 300 mm

Semi-Customizing the Satellite

Canon Electronics' micro satellite transmitted visual images of places all over the planet back to Earth daily. The project was proceeding smoothly, but achieving 100 billion yen in sales by 2030 would still require overcoming a major hurdle—designing an optimal business model for micro satellites.

Currently, the company plans to generate revenue through sales of micro satellites, sales of parts for micro satellites, and sales of the visual data recorded by the satellites. Canon Electronics considers the sales of micro satellites to be the primary driver of this business, and by semi-customizing micro satellites, the price can be reduced and delivery times shortened to expand the market.

However, according to Yoshito Niwa, General Manager, Development Div. 2, Satellite Systems Laboratory, Canon Electronics Inc., "Sales of micro satellites alone will not help us reach that target. The key to expanding business is sales of the visual data." The high-resolution images captured from space contain information that is valuable in many ways. At present, however, Canon is searching for clients who might require such data. What kind of information can be obtained, and who can use it? Going forward, Canon will work to improve its image analysis technologies with the goal of finding the perfect customer match for this information.



With the CE-SAT-I satellite

Nobutada Sako
(left)
Group Executive
Satellite Systems Laboratory
Canon Electronics Inc.

Tsumori Sato
(center)
Senior Managing Executive Officer &
Group Executive
Future Technology Research Laboratory
Canon Electronics Inc.

Yoshito Niwa, Ph.D.
(right)
General Manager
Development Div.2
Satellite Systems Laboratory
Canon Electronics Inc.

Chapter 2

Envisioning the Future

Canon is blazing new trails and cultivating new areas of business.
We expect to see growth in such fields as commercial printing, network cameras, healthcare and industrial equipment.
In striving to become a truly excellent company, it is our enterprising spirit and the pursuit of innovation that will define the future of Canon.

Network Cameras

Advancing

Society

Network cameras are increasingly being used in a range of fields beyond security, such as management and marketing. Canon is working to develop solutions that create new value through such features as advanced video content analysis and the utilization of artificial intelligence.

Canon network cameras are installed in the JAL hangar at Haneda Airport

Ko Misawa
Haneda Aircraft Maintenance Center
JAL Engineering Co., Ltd.

High-Resolution Network Camera Systems Meet the Need for Enhanced Security

Canon's network camera systems, which combine cloud services and image analysis technologies, are helping to drive Canon's business growth. Their use is expanding into a broad range of fields, from security systems for factories, warehouses, and stores to business solutions that analyze flows of people and physical objects for marketing research or to help boost productivity.

JAL Engineering Co., Ltd., which handles aircraft safety and quality control, adopted a Canon network camera system for the company's hangar and facilities at Haneda Airport. Routine aircraft maintenance is conducted in the hangar, along with inspections carried out on an aircraft in the short period of time between its landing and next takeoff. Emergency repairs are also carried out there if a malfunction occurs. Previously, the company employed a monitoring system comprising 60–70 cameras to cover the hangar in which people, vehicles, and aircraft were in constant motion. However, due to increased security needs, they decided to upgrade to a system that offered higher resolution. Ko Misawa, in charge of the project, explains what his company needed in a new security system. "To establish a higher level of safety management, we placed top priority on a system that would produce clear, sharp images. However, wiring issues meant it was not possible to place cameras everywhere in the hangar. To cover every part of the very large hangar, we needed advanced camera functionality that would be able to easily switch between zoom distances, change the direction of the lens and also produce clear images at night. What impressed us the most about the Canon system were models with 20x optical zoom that produces images so clear that it is possible to zoom in and recognize faces. We were also impressed with models that could produce distinct images even in the dark, and cameras that could capture ultra-wide angle shots, even in cramped spaces. Only a camera manufacturer, I felt, could offer such capabilities."

The combination of lens and video technologies cultivated by Canon over its history make possible network cameras that provide high-resolution, high-definition images while maintaining a wide angle of view. The cameras also adjust for optimal shooting day or night, producing clear images from corner to corner.


Canon helps JAL optimize maintenance operations

Optimal Solutions with IT Integration to Cover Any Physical Space

In the process of introducing the new system, Canon's team of engineers repeatedly inspected the physical location and held numerous meetings with the client.

"JAL Engineering had objectives and key locations where we wanted to improve monitoring. We explained these to the Canon team, and they set about designing a plan. It was difficult to place cameras in some spots, and wiring would not reach certain zones, but the engineers came up with workarounds for every situation and set up an extensive web of 128 network cameras. We are very proud of this security system that we built together with Canon."

A further evolution was the addition of a high-capacity data management system.

"Thanks to cutting-edge data compression technologies, it is now possible to store video for long periods of time. If a problem occurs, we can now go back in time and view video in chronological order to thoroughly troubleshoot the issue."

Canon has created a monitoring system that reduces the load on the network even when transmitting high-quality video, thanks to an image compression system that realizes high image quality with a high compression ratio. High compression reduces hard disk drive capacity requirements and makes it possible to store recorded video for a long time, enabling the high-volume storage of footage from multiple cameras.

Overcoming On-Site Challenges to Improve Operations—the Expanding Possibilities of Network Cameras

"When the completed system began operation, we witnessed improvements on the hangar floor," says Misawa.

"Before, when an aircraft was late to arrive, no matter how many times contact was made with the aircraft, the waiting resulted in lost time at the hangar. After the system was introduced, it became possible to check a monitor and see the aircraft coming in or leaving in real time. Additionally, we could now confirm work progress using the cameras."

The primary mission of maintenance crews is to complete the work properly and flawlessly in the limited time available.

"At JAL Engineering, we created the term 'Zero Zero 100' to represent our goal of *zero* irregular operations, *zero* in-flight malfunctions and *100%* on-time departures. I feel that the system renewal has achieved improvements to that end in both security and productivity."

Canon's network camera system watches over the aircraft maintenance floor and helps to improve business operations. Using the power of cutting-edge technologies, Canon will continue promoting safety and security in a range of different fields.

Safety and Security through the Synergy of the Canon Group's Cutting-edge Technologies

As part of a strategy to strengthen and broaden its network camera business, Canon has welcomed two major global players in the fields of network cameras and video management solutions into the Group—Axis Communications (Sweden) and Milestone Systems (Denmark).

Axis Communications is the global network camera market leader, offering an extensive product lineup. They have also launched the AXIS Q1659, a network camera that combines the company's network technologies with Canon's optical technologies to make possible high-resolution visual monitoring.

Additionally, the combination of Milestone Systems' video management technologies and Canon's image analysis technologies is giving rise to business solutions that utilize visual data in various ways.

For example, the integration of Milestone Systems' video management software with Canon's image analysis software has produced *People Counter*, which counts people in real-time and recorded video. Through the integration of cutting-edge technologies, Canon's network camera solutions are continuing to evolve, realizing higher performance and utilizing AI and IoT technologies to derive new information from images and create new value.


AXIS Q1659

A high-resolution network camera that makes possible color shooting from wide-angle to telephoto at approximately 20 megapixels and 8 frames per second.

CT Scanners

Leading

the World

In 2016, the pioneer of medical diagnostic imaging Toshiba Medical Systems Corporation (now Canon Medical Systems Corporation) joined the Canon Group. The synergy between Canon Medical's diagnostic imaging systems and Canon's optical and image processing technologies positions the Canon Group at the forefront of efforts to build a better future for a society.

Canon Medical collaborates with Fujita Health University Hospital in joint R&D efforts in CT technology.

The Aquilion Series: at the Forefront of CT Technology

The history of Canon's medical device business reaches as far back as 1940, shortly after its foundation, when the company developed Japan's first indirect X-ray camera. Since then, Canon has leveraged the optical and image-processing technologies cultivated through camera development to introduce such leading-edge medical equipment as digital radiography systems and ophthalmic diagnostic equipment. In order to take its medical business to the next level, Canon welcomed Toshiba Medical Systems Corporation (now Canon Medical Systems Corporation) into the Canon Group in December 2016. Canon Medical boasts the top share of Computed Tomography (CT) systems in the Japanese market and ranks third* globally.

Since its development, CT technology has continued to evolve in response to demand from the medical community for imaging that is *wider*, *faster* and realizes *higher resolution*, all while reducing patient radiation doses.

Wider imaging was achieved with the introduction of the Aquilion ONE in 2007, which featured a 320-row area detector capable of scanning a 16 cm-wide section of the body with each rotation. The *faster* system also made possible the capture of image data for such major internal organs as the heart or brain with only a single rotation at a maximum scanning speed of 0.275 seconds per rotation.

Canon Medical collaborates with several medical institutions in the development of Aquilion-series CT systems. A CT system comprises an X-ray tube and X-ray detector that rotate around the patient's body to create a tomographic image. X-rays transmitted from the X-ray tube pass through the patient and are captured by the detector on the opposite side. This information is then rendered as an image by a computer. With early CT systems, one tomographic image, or a virtual "slice", was created per revolution of the X-ray tube and detector. Later increases in the number of detector rows led to the development of multi-slice systems capable of capturing several images in a single rotation, with the Aquilion ONE system able to deliver 320-row, 640-slice tomographic images in a single rotation—a world first. This permitted not only morphological diagnostics, but also allowed real-time observation of areas of interest such as internal organs and joints.

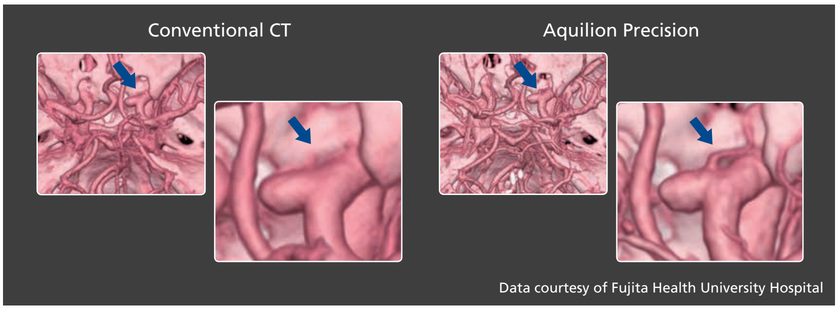
This evolution was achieved by working with medical personnel and technicians in the field to resolve problematic issues one by one. Yet, rather than simply incorporating new technologies into the system and

ending the development process there, repeated improvements were made based on feedback from physicians and medical professionals until the system was ready for commercialization.

2017: The Aquilion Precision Ushers in a New Age of CT

Over the last 30 years, technological progress toward *higher resolution* has been slow. However, Canon Medical overcame that impasse through successfully realizing higher-resolution imaging with the release of the Aquilion Precision in April 2017. The system was a world first, released in response to demand from the medical community for technology to produce clearer images of the human body.

The Aquilion Precision CT system delivers more than double the spatial resolution of



Comparison of CT images of cerebral aneurysm and ophthalmic artery (from same patient)

conventional systems in both the vertical and horizontal planes through the body.

This system allows the rendering of clear images at the intravascular and peripheral blood vessel level, a task that conventional CT systems find difficult. Canon Medical's new CT system makes it easier to detect pathological changes within the body, such as early-stage cancer or aneurysms, holding great promise in early diagnosis and treatment of these conditions.

Tackling Difficult Challenges with Technical Expertise

Since 1986, CT systems have been capable of resolving images up to 0.35 mm. Progress in visualizing finer detail was hindered by the fact that resolution could not be improved without corresponding increases in radiation dose to the patient. However, Canon Medical made a breakthrough in 2011 with the development of AIDR 3D, a technology that made it possible to take images with reduced radiation dose. Canon Medical then set about implementing this new technology in all of its CT systems. It also significantly improved two principal units—the X-ray tube and X-ray detector—to enhance resolution without increasing the required radiation dose. The result was the Aquilion Precision, which with a resolution of 0.15 mm more than doubled the resolution possible previously.

Canon Medical has also developed new technology that enables radiographers to adjust the size of the X-ray tube's focal spot. By subjecting the electron beam emitted to the target for X-ray generation to an electric field, the electron beam can be narrowed by more than half, resulting in greater focus control. Applying an electric field in this way is like creating an "electrical lens" in the X-ray tube. Moreover, to improve the resolution of the X-ray detector, newly developed ceramic materials and machining processes were utilized, enabling a reduction in pixel size to one quarter that of the pixels found conventional X-ray detectors.

Looking ahead, Canon's optical, image processing, and manufacturing technologies will continue to find synergistic applications in improved detectors, image processing and manufacturing technologies, as well as in advances in software for assisted analysis of high-resolution image data from CT scans and AI-based medical diagnostic support. These advances, made possible by combining the strengths of Canon and Canon Medical, will open up a wealth of new possibilities.

*According to a Canon survey

A clinical evaluation of the Aquilion One CT system. Photographed at Fujita Health University Hospital

Photoacoustic Tomography

Aiming

to Improve Healthcare

PAT is imaging technology that can capture 3D images of blood vessels in real time. We aim to contribute to healthcare with new diagnostic imaging equipment that combines cutting-edge optical technology, ultrasonic technology and image processing technology.

Image of blood vessels in the hand captured in 3D using photoacoustic tomography

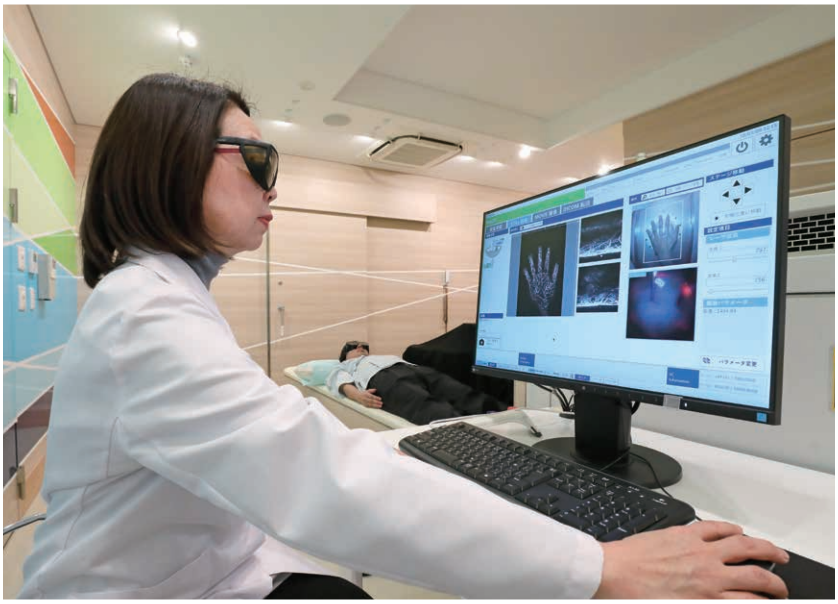
Taking 3D Images of Blood Vessels

As awareness of a healthy life expectancy increases, the early diagnosis of such lifestyle-related diseases as cancer and diabetes and treatment tailored to the individual are becoming increasingly important.

Canon is currently developing Photoacoustic Tomography (PAT), a leading-edge technology to improve healthcare through the early diagnosis and appropriate treatment of diseases. This technology was selected as a research topic for ImPACT (the Impulsing PAradigm Change through disruptive Technologies program) being implemented by the Council of Science, Technology and Innovation of the Cabinet Office in Japan.

PAT is technology that uses both light and ultrasonic waves to noninvasively capture 3D images of human blood vessels in real time without using X-rays or a contrast agent. When the human body is exposed to near-infrared laser light, red corpuscles in blood vessels absorb laser light, heat up and undergo thermal expansion, increasing their volume. The laser light is transmitted in pulses, so the exposure is short-term, and the expanded red corpuscles in the blood vessels soon cool off and return to their normal state. The effects of the expansion and the contraction are transmitted to neighboring soft tissue and are emitted from the surface of the body in the form of ultrasonic signals that can be detected by an ultrasonic sensor. This is the mechanism of PAT.

The laser light has a wavelength of 750 nm to 850 nm (nm = nanometer, one billionth of a meter); a pulse width of laser light is several nano seconds and has a repetition frequency of about 10 Hz. The ultrasonic sensor



Recreating a 3D image in real time at Kyoto University

has 1024 piezoelectric elements attached to its hemispherical inner surface.

Making Blood Vessels Visible and Precisely Determining their Position

The challenge is the high number of blood vessels in the human body that generate ultrasonic signals throughout the body. The ultrasonic signals are conveyed as they expand to surrounding areas, making it difficult to determine which ultrasonic signal originated from which blood vessel at what location. Canon uses the image processing technologies that we have cultivated through the development of various imaging devices to successfully recreate a 3D image in real time based on the received ultrasonic signals.

Among the features of PAT is the ability to capture images from a wide range of areas—such as the hands and feet—the ability to make blood vessels as small as 0.2 mm visible, and high resolution imaging that allows for the position of each blood vessel to be determined individually. In addition, blood vessels are made visible to a depth of several centimeters, something that is difficult to achieve using light alone.

Potential to Lead to Early Diagnosis and Appropriate Treatment

The 3D images of blood vessels captured by PAT are giving rise to ideas for applications in the early diagnosis of diseases and assessment before and after treatment. For example, diseases of the blood vessels and skin and such diseases as cancer can lead to inadequate blood circulation in the periphery of the limbs, irregularities in the shape of blood vessels and abnormal blood vessel growth. If it is possible to detect these symptoms and recognize minute changes at an early stage, such applications as the early identification of disease status, selection of appropriate treatment and post-treatment evaluation may be made possible.

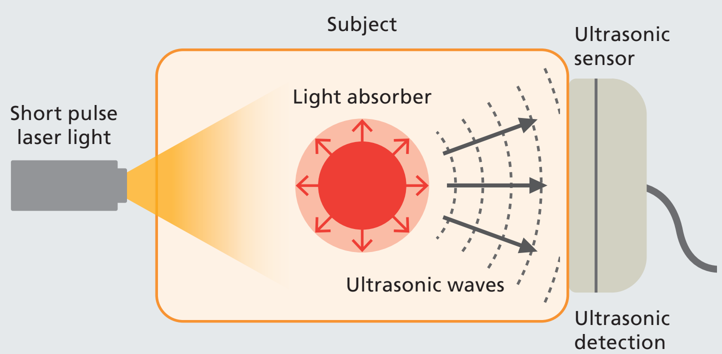
Joint Research with Kyoto University and Keio University

PAT is also characterized by the ability to distinguish between arteries and veins using a number of wavelengths of laser light. When the laser light wavelength is shortened, the ultrasonic signals emitted from arteries, which contain more oxygen, decrease compared with veins. In addition, images that reflect the oxygen saturation of blood can be captured through the use of multiple laser lights of different wavelengths. Use of these features makes visible changes resulting from the progression of a disease or the effects of treatment, as well as the amount of oxygen consumption in tissue and the volume of blood circulating. This holds promise for such applications as the diagnosis of peripheral artery disease caused by lifestyle-related illnesses, as well as skin conditions and cancer.

Canon is conducting clinical research using PAT in collaboration with Kyoto University and Keio University. The research with Kyoto University has produced results in the capture of 3D images of blood vessels that concentrate in the vicinity of a cancer tumor. Further research is needed to determine the direct relationship between the 3D images and the disease, but the accumulation of this type of knowledge increases the likelihood of clinical applications of this technology.

PAT is noninvasive, nondestructive and does not require X-rays or a contrast agent; it causes absolutely no harm to the human body. Canon is conducting development with the hope that one day, PAT imaging devices will be installed in hospitals alongside X-ray, CT diagnostic systems and MRI scanners, and contribute to the early diagnosis of disease and the evaluation of treatment.

> The Mechanics of Photoacoustic Tomography



The subject is exposed to laser light, which is absorbed by absorbers. These absorbers undergo thermal expansion and emit ultrasonic sound (known as the photoacoustic effect). This sound is detected by spherical ultrasonic sensors.

Medical Imaging

Developing

New Medical Technology

Canon is working with leading research institutions in the U.S. at the forefront of modern medicine to apply its advanced optical and imaging technologies to leading-edge medicine.

[Ultra-Miniature Fiber Endoscope]

Extremely Thin Endoscope to Offer New Diagnostic Possibilities

At the Healthcare Optics Research Laboratory (HORL) in Boston, Canon U.S.A. is leveraging Canon's technological strengths in such areas as micro-optics fabrication technology, diffraction optics simulation, and optical design technology to develop a less than 1 mm diameter ultra-miniature fiber endoscope. It consists of a micro-lens and a diffraction grating attached to the end of the optical fiber. The high-resolution endoscope will be significantly thinner than conventional devices and robust enough to maintain its integrity within the body. When commercialized, the device will enable real-time observation of the intra-articular and intranasal cavity regions for the first time, facilitating early treatment and new forms of diagnostics.

Ultra-miniature fiber endoscope currently under development for final product

Prototype needle-guiding system composed of image-guided navigation software and needle insertion robot

[Needle-Guiding System]

Image-Guided Navigation Software and Robot for Accurate Needle Insertion

A physician generally will view CT or MRI images outside of the operating room to confirm the location of a cancer site or to decide where to position a needle. With this system, being developed by HORL, however, the physician specifies the target position for the needle to be inserted into the abdominal or chest cavity using image-guided navigation software. This will be done with the device that sets the angle of insertion accordingly and guides the physician to ensure that the needle correctly reaches the targeted organ location.

In creating a prototype of the needle-guiding system, Canon has been developing motors and sensors that operate in an MRI environment. This system aims to bring greater speed and accuracy to such procedures as biopsies or ablations (treatments using either high or low temperature to destroy cancer cells), which generally rely on a physician's intuitions and skills.

The ultra-miniature fiber endoscope and needle-guiding system are being developed for commercialization in collaboration with Massachusetts General Hospital and Brigham and Women's Hospital, both teaching hospitals of Harvard Medical School, in Boston, Massachusetts.

[A Genetic Testing System]

Faster, More Accurate Testing for Research on a Wider Range of Diseases

Genetic testing makes it possible to identify individual susceptibilities to congenital disorders, the likelihood of contracting a disease, and potential side effects of medications. In the United States, Canon is developing genetic testing systems that can perform complex tests in a matter of hours.

Canon U.S.A. established Canon BioMedical (CBMI) in March 2015, aiming to commercialize a genetic testing system made up of testing instruments and reagent cartridges that leverage such core Canon technologies as CMOS sensors and inkjet printing technologies. In September 2015, CBMI launched Novallele Genotyping Assays and their associated reagents, that test for specific DNA sequences used in cancer and hereditary disease research, which went on sale in the United States for research settings. Novallele takes a specific base sequence from DNA, amplifies it, and analyzes the gene, making it possible to detect variations in parts of a genetic sequence or even small genomic indels. The Canon BioMedical team continues to develop these reagents to efficiently amplify DNA and make gene variations easier to find, expanding the number of targets for research to 500 diseases.

Genetic testing system under development at CBMI

Nanoimprint Lithography

Exceeding
the Limits of Miniaturization

Semiconductor lithography equipment is used to transfer circuit patterns on a semiconductor chip. By making further miniaturization possible at low cost, Canon's nanoimprint lithography technology is about to trigger a revolution in semiconductor manufacturing.

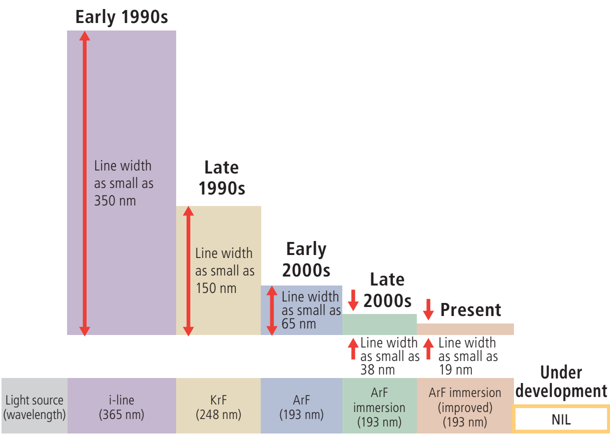
Canon's FPA-1200NZ2C nanoimprint semiconductor lithography equipment in use at Toshiba Memory's Yokkaichi Operations plant, Japan.

Nanoimprint Lithography: The Ultimate Microfabrication Technology

The evolution of semiconductor chips correlates directly to the history of circuit miniaturization. The key to this miniaturization has been the shortening of light-source wavelengths and advances in lithography technologies. In the early 1990s, Canon introduced its i-line 365 nm wavelength (nm = nanometer, one billionth of a meter) steppers, making 350 nm resolution possible for a variety of imaging applications. In the late 2000s, new shorter-wavelength light sources were developed, leading to the creation of an argon fluoride (ArF) immersion lithography system capable of 38 nm-resolution patterning. At the time, it was believed that miniaturization had reached its technological limit.

As the industry looked for further breakthroughs, including extreme ultraviolet (EUV) lithography, Canon sought alternatives to shorter wavelengths, establishing a new approach to circuit miniaturization. That approach was nanoimprint lithography (NIL), which exceeds conventional lithographic limitations and does so at lower cost. Capable of achieving line widths of under 15 nm using a simple, process that lowers manufacturing costs, NIL is poised to revolutionize the semiconductor industry.

The History of Semiconductor Miniaturization



While line widths have halved roughly every five years, progress has stalled since the late 2000s

Overcoming Numerous Technological Challenges

Unlike conventional lithography technology that uses light to expose circuit patterns, nanoimprint lithography fabricates nanometer-scale patterns by transferring the nano-pattern mask (mold) onto the coated resin on the wafer surface to form circuits. Because the process involves no optical system, it enables the faithful reproduction of the mask's minute circuit patterns on the surface of the wafer. However, because the circuit patterns are formed using direct transfer, the process requires nanometer-level control technologies for accurately positioning the mask and wafer, eliminating particle contaminants and other operations. Through the comprehensive development of hardware, software and materials technologies, along with environmental control technologies to keep microscopic particles in check, Canon successfully overcame these numerous obstacles.

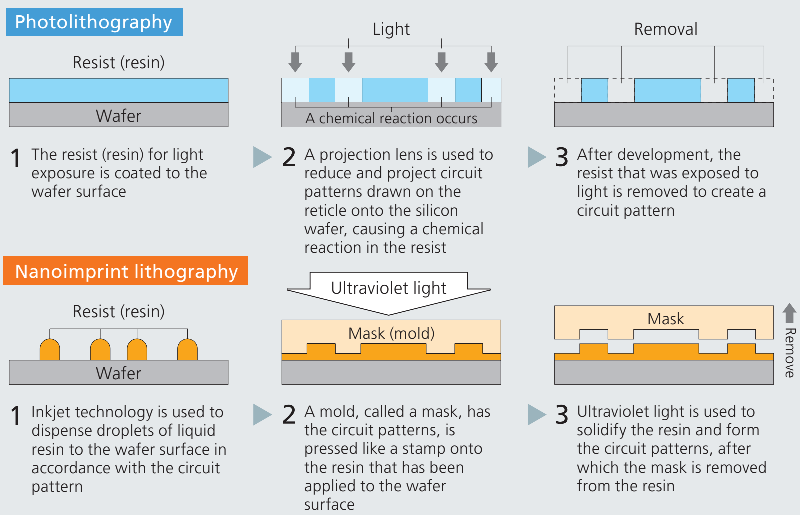
One of the technologies Canon developed for nanoimprint lithography controls the amount and positioning of the resin that is applied to the wafer surface. This technology precisely controls how much and where the resin is applied to prevent it from being squeezed out when the mask is pressed into the resin, while also ensuring the formation of a resin layer with a uniform thickness. Likewise, when the mask is removed from the wafer, their relative positions must be optimally controlled to prevent the deformation of the convex circuit patterns formed in the resin.

Generating Synergies from Different Cultures

With the aim of mass producing nanoimprint lithography systems, Canon is collaborating with U.S.-based Canon Nanotechnologies, Inc. (CNT), which boasts some of the world's most advanced and unique technologies for microfabrication devices in the field of nanoimprint lithography. In addition to lithography system control and measuring technologies achieved through Canon's development of semiconductor lithography systems, Canon's service and support know-how will be merged with CNT's cutting-edge nanoimprint lithography technologies to break down the current barriers to miniaturization, once thought inviolable.

How Canon Nanoimprint Lithography Works

While photolithography has contributed to reducing the cost of semiconductor chips, further miniaturization required various work arounds that resulted in ever-larger and more expensive lithography systems. In contrast, nanoimprint lithography offers the simple approach of physically pressing patterns on a mask onto the resin. The simplified manufacturing process has the potential to significantly lower costs. Also, because this approach produces extremely sharp circuit patterns, it is expected to contribute to lower chip-defect rates.



Visualizing

Parts

Highly accurate recognition of the location and orientation of randomly piled parts in three dimensions facilitates the automation and acceleration of production lines for parts feeding.

3D Machine Vision system in action on the components production floor at Canon.

Using 3D Machine Vision to Solve Issues on the Production Floor

While robots play an essential role in the manufacturing industry, there are some tasks for which they are ill-equipped. One such task is the selection and pickup of individual parts from randomly piled parts in a box or on a pallet.

This meant that workers would have to position each part at a designated spot for pickup by robot, creating a bottleneck amid efforts to streamline and automate production lines.

Canon's 3D machine vision system solves this issue. Machine vision refers to the use of industrial image sensors to recognize the position and orientation of parts. The most common form of machine vision currently in use is 2D machine vision, which has difficulty with randomly piled parts. As a solution, Canon developed the RV Series of 3D machine vision system capable of high-speed, high-accuracy three-dimensional recognition of objects. This system enables the automation of parts supply on production lines, a task that conventionally has had to be performed manually, and opens up new possibilities on the front lines of manufacturing. Canon offers three models in its machine vision product lineup—the RV300, RV500, and RV1100—which can pick up parts from small to large to suit a wide range of production lines.

Easy Installation with Integrated Projector and Imaging Sensor

Canon's 3D machine vision system projects recognition patterns onto randomly piled parts and analyzes the projected images. Based on the analysis of the differences between images of the parts and the multiple projected patterns, the systems are able to recognize targeted objects in three dimensions. Conventional 3D machine vision systems are very difficult to calibrate upon installation. Canon's 3D machine vision system combines the pattern projector and imaging sensor into a single unit, which makes the system compact and lightweight, and eliminates the need for difficult calibrations. The compact design also allows the system to be moved easily when changes are made in a production line or the line is relocated.

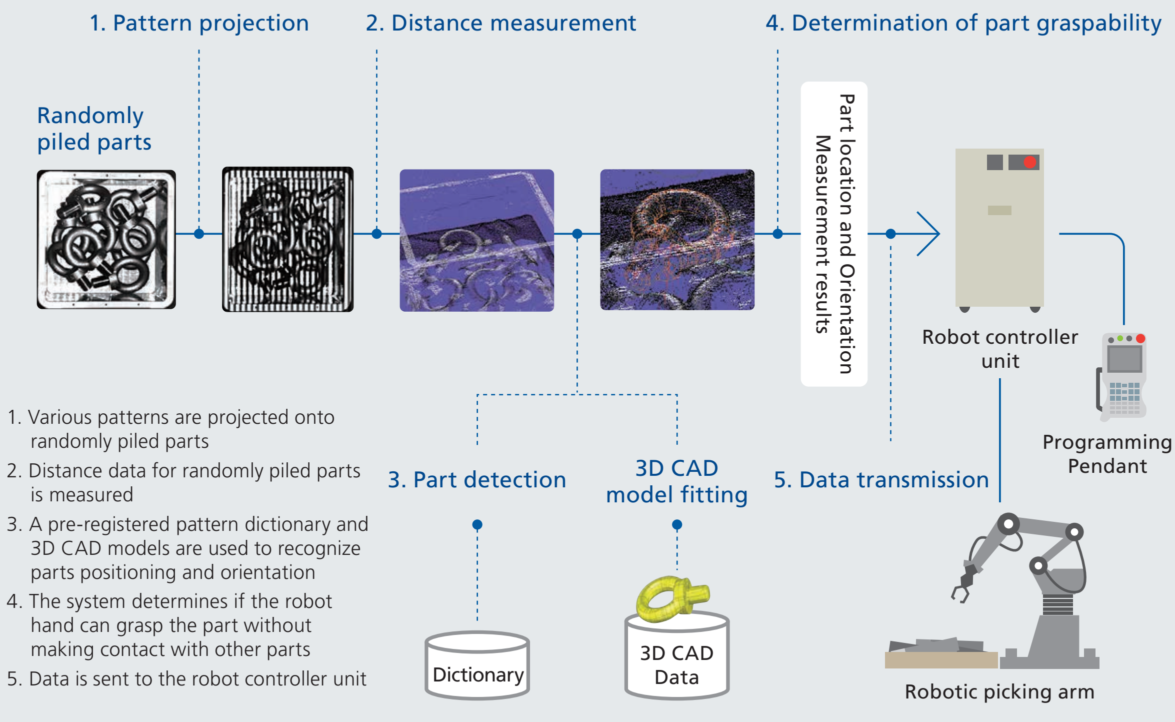
Additionally, the system features a dust- and water-resistant body design for maintenance-free operation, and easy operation through a well-designed software interface.

Reaching Higher Speeds and Higher Precision in Parts Recognition

Canon's 3D machine vision system delivers unrivaled recognition precision. The system is applicable for parts with curved surfaces, parts with few distinguishing features, and even parts with more complex shapes. Users can easily register parts simply by inputting the CAD data and capturing images of the randomly piled parts. Also, a new approach that matches CAD data with distance measurement data and gray-scale images allows the system to recognize a wide variety of parts with high precision. The system is being adopted by manufacturers across a range of industries, including automotive, electronics, metal equipment, resin and chemical industries. Canon also aims to expand its business in the future through the introduction of systems for assembly processes and the automation of defect inspections.

Scan to access a special video and learn more about 3D machine vision

3D Machine Vision System Workflow



Commercial Printing

Changing

the Future of Printing

Short-run production for a broad range of applications and variable-data printing—the printing industry is undergoing a major transformation, from offset printing to digital printing. Canon is pursuing commercial printing solutions tailored to customer needs.

Leveraging the advantages of Digital Printing to Enter the Commercial Printing Market

Although such commercial printing jobs as producing publications and brochures can involve print runs ranging anywhere from tens of thousands of copies to several million copies, there is an increasing need for short-run production for a broad range of applications. Additionally, printing paper has become diversified as various types of media including glossy paper, pressure-bonded paper, carbonless paper and heavy paper are now used in the market. Because offset printing requires printing plates, while digital printing does not, digital demonstrates superiority for individual print jobs containing short run length and wide range of applications and variable-data printing, in which content can be changed from one page to the next. To meet demand in the growing digital printing market, Canon is working hard to improve quality, productivity and reliability.

Promoting In-House Production of Diversified Content

Offering such products as continuous-feed printers and large-format inkjet printers enables the Canon Group, which includes Océ, to provide optimal solutions tailored to customer needs. One of the advantages enjoyed by our customers is uniform operability and user interfaces, which deliver the same experience across various products.

In 2014, Asahi Shimbun Company became the first newspaper company in Japan to introduce digital printers and is now working towards developing unique businesses. When Asahi Shimbun was looking to introduce new printers, they appreciated Canon's collaborative problem solving system and ability to respond to technical issues and ultimately selected Océ inkjet printers. By taking full advantage of the printers' characteristics, including variable-data printing, special folding and long-sheet printing, Asahi Shimbun is able to produce highly varied content. As an example, a project involving a special feature on a marathon tailored to individual participants—containing such information as the race conditions on the day and the course route—could have a front page with such personalized content as the individual runners' names and running times. The future of newspaper printing has arrived.

At Asahi Shimbun Company, Océ inkjet printers are contributing to the development of new businesses through such applications as variable-data printing

An Extensive Lineup Spanning the Entire Commercial Printing Sector

Canon's strengths lie in our emphasis on speed, image quality and durability and in our extensive product portfolio suitable for all situations. For our continuous-feed printing systems, which print on rolls of paper for large volume production, Canon is working to expand applications with the support of variable-data printing and printing on special paper. Additionally, our cut-sheet printers, ideal for smaller volume production, offer the flexibility to handle everything from the printing of books and manuals to such high-image-quality print jobs as photobooks. Looking to the future, Canon has set its sights on the rapidly-growing package printing sector, aiming to expand the potential of digital printing.

Strengthening Global R&D through Collaboration with Océ

Océ, a Dutch company with a proud history spanning more than 140 years, joined the Canon Group in 2010. The competitive printers developed by Océ have gained a high reputation within the market for their reliability and production capacity. Through collaboration with Océ, which boasts a strong presence in the high-end segment of the commercial printing industry in Europe, Canon is strengthening its R&D capabilities—representing another step toward the realization of Canon's Three Regional Headquarters management system, which aims to spur innovation in Japan, the United States and Europe. Through the synergy between the products and technologies of both companies, Canon continues to expand the horizon of solutions in the field of commercial printing.

R&D at Océ

Chapter 3

Canon Keeps Doing What Canon Does Best

Canon is a brand known for producing clear, sharp images.
The brand is backed by a wealth of intellectual property and exceptional technological strength that extends from highly creative product design to the development of materials.
Here we introduce some of the tireless efforts being made at Canon to ensure that we live up to our global reputation.

Enhancing

Brand Value

Corporate image is not limited to products and services; the impressions made by advertising and publicity also play a role in its formation. Through the proposal of new value and the creation of high-quality designs in harmony with all corporate initiatives through which Canon engages with its customers, Canon Design contributes to boosting the company's brand value.

Design for Product Quality

Canon offers a diverse product portfolio that includes not only a broad lineup of cameras, video camcorders and inkjet printers for both professional and general users, but also a wide range of office-use products, such as copying machines and projectors, as well as industrial products like medical equipment and semiconductor lithography systems. The company also offers web services that provide users with additional ways to enjoy photography.

Aiming to deliver optimal ease of use across a range of usage scenarios, Canon surveys and analyzes customer usage environments, needs and preferences, while focusing on appealing designs that enhance user convenience.

Design in Corporate Activities

Aside from products, design also plays an essential role in such areas as Canon's environmental initiatives, CSR activities and recruiting efforts.

The messages that the company issues, both to customers and employees, must communicate and be easy to understand—yet another indispensable role of design.

Design for Tomorrow

What will our world look like five or ten years from now? What changes can we expect to see in the workplace and in our lifestyles? And how will design influence these developments? Canon Design envisions future scenarios and proposes products and services that embody their vision, another important job that is essential for the future of Canon.

Study-Abroad Program for Engineers

As part of the company's R&D globalization efforts, Canon offers a study-abroad program for its engineers. The Canon Design Center also sends company designers overseas on this program. As a result, overseas-study experiences are being put to substantial use in the design development process.

Design Awards

The Canon Design Center proactively participates in design competitions both in Japan and overseas and has been recognized with Good Design Awards, iF Design Awards and numerous other awards. The opportunity to have designs evaluated by knowledgeable outside authorities not only enhances the quality of Canon designs, but also leads to the growth of the company's designers.

Material Appearance Acquisition and Printing Technologies

Reproducing

Texture and Feel

Canon technologies can reproduce not only the color and shape of objects, but also their surface elevations and gloss. Utilizing such devices as digital single-lens reflex (DSLR) cameras and printers, we are leveraging our technologies that span from input to output to develop technologies that recreate the feel of objects.

A reproduction of Johannes Vermeer's "Girl with a Pearl Earring" kept at the Royal Picture Gallery Mauritshuis (Netherlands)

The material appearance acquisition and printing technologies being developed by Canon enables for the creation of high-resolution reproductions of famous art works such as oil paintings.

One example of Canon's work is with Vermeer's masterpiece. Canon's material appearance acquisition and printing technologies can faithfully reproduce brushstrokes on the canvas, the buildup of paint, the gloss of the finishing varnish and even the cracks in the surface from many years of aging. By displaying these reproductions, people can get up close to works of art and even touch them, rather than viewing them through glass in a gallery. These material appearance acquisition and printing technologies are not limited to paintings—they can also reproduce the textures of fabrics such as velvet and denim, as well as leather, rattan, gold leaf and many other materials. It is expected that such textures could also be employed in building interiors and exteriors, product packaging and many other areas.


Image processing: A technician calculates elevation and gloss data

[Material Appearance Acquisition / Image Processing]

Digitally Capturing Color, Surface Elevation and Gloss Information and Reproducing it with a Printer

Texture is both a visual and tactile element of objects experienced by people. Therefore, in addition to the color and flat appearance of an object, it is essential to digitalize such information as elevation and gloss. Canon's material appearance acquisition and printing technologies reproduce this textural information through image capture, image processing and printing.

Using High-Resolution Image Capture to Estimate Elevation and Gloss

Canon DSLR cameras capture information on the subject's color, surface elevation and gloss. The subject is photographed repeatedly while changing the position of the lighting and cameras.

Capturing the images in high resolution is a crucial point. Reproducing texture that is identical to the original requires data of the same resolution as the human eye. To achieve this resolution, 50 megapixel DSLR cameras are used to take repeated close-up images of postcard-sized areas of the original. Processing the images to acquire surface elevation and gloss information at a resolution of tens of micrometers (micrometer [μm] = one millionth of a meter).

When performing the image processing, the object's elevation and gloss are estimated from the multiple captured images. With regard to elevation, a fixed pattern is projected on the painting and the reflections are analyzed to calculate where surface elevations are located and how high they are. Gloss is determined by identifying and quantifying changes in reflected light occurring as a result of capturing images at different angles. These parameters are saved as gloss data.

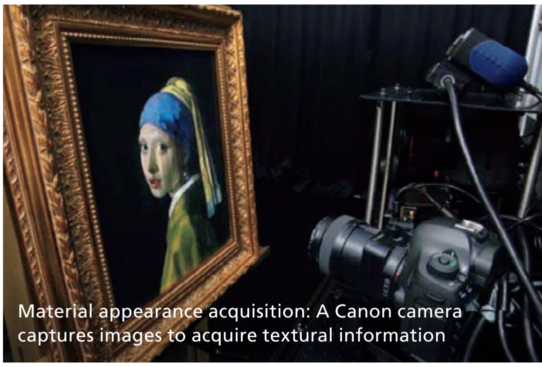
[Printing]

A UV-Curable Printer that Recreates Detailed Elevation

To print the image, UV-curable printers developed by Océ, a Canon company, use ultraviolet (UV) light to cure printed ink.

The first step in recreating texture in print is to convert the quantified color, elevation and gloss information to print data. For the colors, technology developed for photo printing is used. RGB (red, green, blue) images captured by the cameras are converted to CMYK (cyan, magenta, yellow, black) printer colors. The surface elevation is recreated by repeatedly performing ink layering and curing. Finally, the gloss can be recreated in fine detail by taking into consideration the volume, placement and layering of ink to control the ink ejection and in turn the smoothness of the printed surface.

Scan to access a special video and learn more about Canon's material appearance acquisition and printing technologies.


Material appearance acquisition: A Canon camera captures images to acquire textural information


Printing: A UV-curable printer developed by Océ

Research on Materials

Creating

Materials from Scratch

Material science is an integral part of product competitiveness, applied to the development of colorants, toners, and optical glasses.
From the 1980s, Canon has been undertaking research on such materials, and has created a corporate database called Canon Material Bank, with company-wide accessibility.

[High-Color-Performance Xanthene-Based Dyes]

Permanent Vivid Red

In most cases, since printer manufacturers do not develop original colorants in-house, and procure commercially available dyes from suppliers, it is difficult for them to differentiate their products from competitors in color appearance. Canon, however, recognized the high color properties of xanthene-based dyes, and started to develop such vivid red dye in-house. Although such xanthene-based dyes were considered difficult to put into practice due to their weakness against image permanence, lightfastness, Canon tackled this issue and successfully created a new magenta dye, a Vivid Red with permanence.

In Search of Improved Image Permanence by Structuring Proprietary Molecular Design

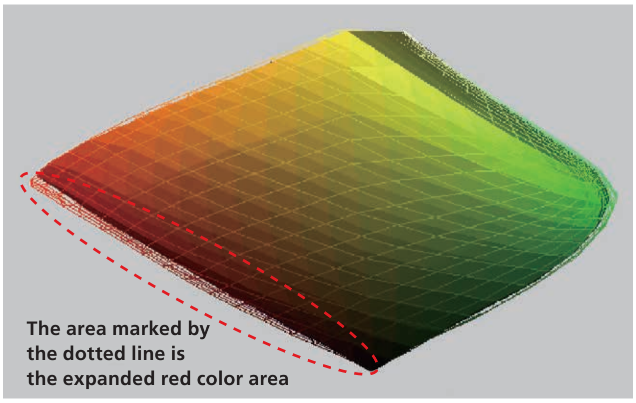
Canon began developing new dyes in the 1980s, which is now all registered in the database called, Canon Material Bank, boasting more than 10,000 types of dyes. Various technical information and knowhow are also stored, along with information on their physical properties and synthesis, for example, the mechanisms behind the breakdown of dye structures when exposed to stimuli such as light and ozone gas. During the development of such xanthene-based dyes, repetitive studies and simulations were made on molecule designing, synthesizing, then analysis and evaluation, using materials in the database stock. By locating specific substituents at the suitable places of the dye structure, enabled a birth of a new dye with both vivid color and image permanence.

It was 2012 when the first original dye was used in the ink for cartridge BCI-351. Modified generation two novel dye was applied to cartridge XK1-N11, released in 2017, which contributed to improved print quality.

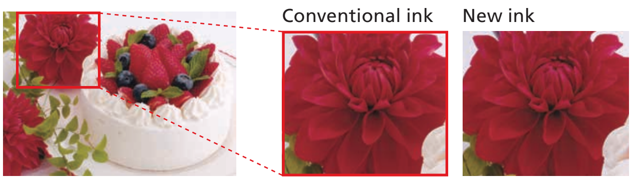
The Challenges of Moving from Lab-Scale to Mass Production

The success in creating a new dye on a lab-scale is only the first step. Achieving production on a full-scale is required for commercialization. Compared to the small 300 mm size reactors in the laboratory, those used in mass production are on a one ton scale or larger, completely on a different scale-order. With inkjet printers, which eject ink droplets in the unit of picoliters, any slight track of impurities, generated during synthesis, could lead to ink clogging at the nozzles of the printhead. A joint research was made with the business group and corporate research center, resulting in controlling the impurity level below one part per million. The collaborative effort paved the way for commercialization, ensuring consistent ink quality on a full-scale.

Note: Without protective gear for photo-purpose only



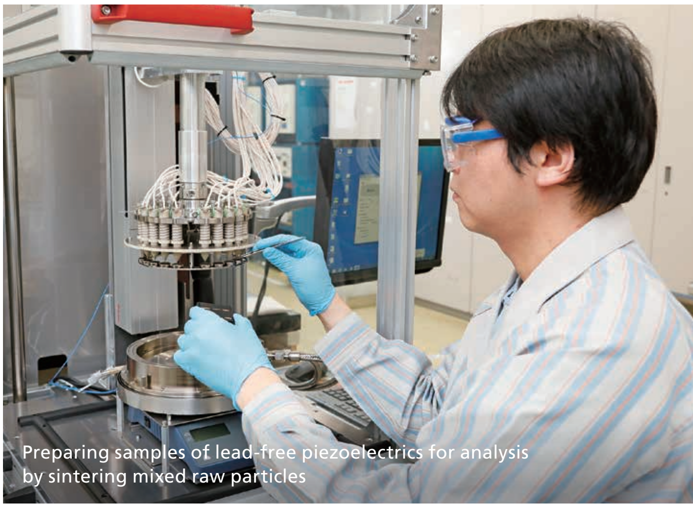
The new ink in the new XKI-N11 ink cartridge has a wider color reproduction range in the red area than conventional ink.
Solid: Color reproduction range of conventional ink
Wire: Color reproduction range of new ink



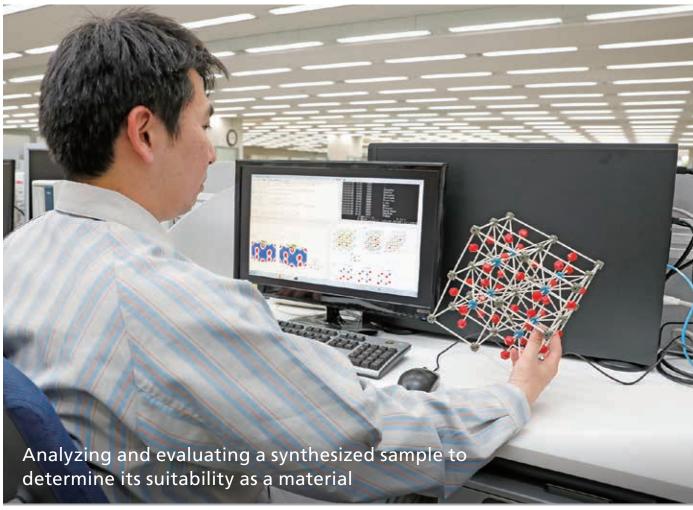
[Lead-Free Piezoelectrics]

The Development of Piezoelectrics with Low Environmental Impact

Piezoelectric materials, which are essential for motors and sensors, have the ability to transform electrical energy into mechanical energy. Most piezoelectric materials, however, include lead. Lead has a negative impact on the environment, which has become an issue within the industry. Canon eliminated lead from solder and optical glass for lenses, and has been developing lead-free piezoelectric materials, which are implemented in new Canon products.



Preparing samples of lead-free piezoelectrics for analysis by sintering mixed raw particles



Analyzing and evaluating a synthesized sample to determine its suitability as a material

Participation in Japan's National Project

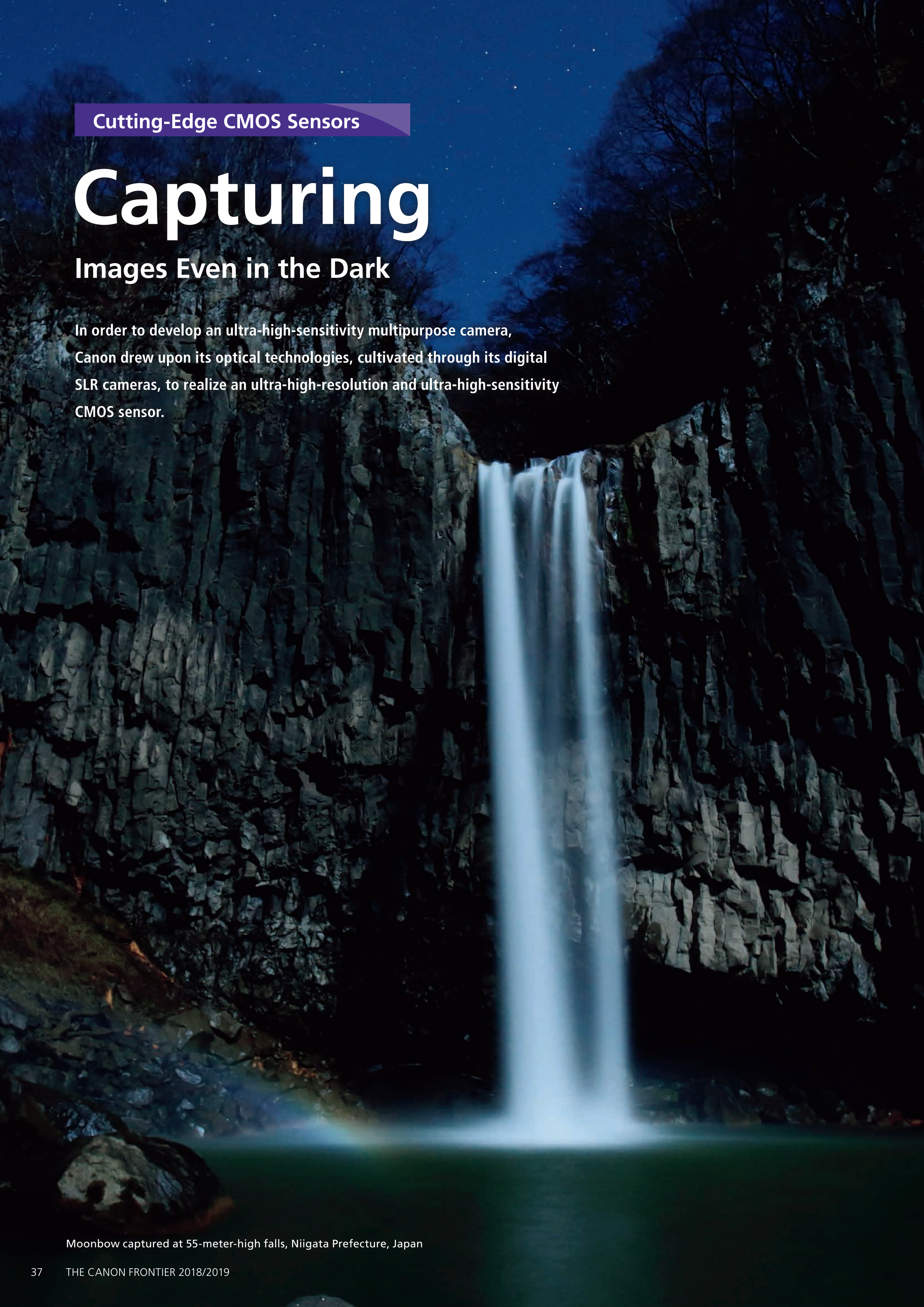
From 2007 to 2012, Canon participated in a national project called, "Element Strategy Initiative", launched by Japan's Ministry of Education, Culture, Sports, Science and Technology. Working on lead-free piezoelectric materials at Canon was one of the goals of the project, to create new high performance materials. By studying the properties of elements that structure substances, and understanding their roles, the mechanisms behind realizing such performances became clear. Although the goal of the research was to create new materials that do not contain environmentally hazardous elements, Canon was able to create piezoelectric materials that is not only environmentally-friendly, but also with higher piezoelectric performance, exceeding widely used lead-based piezoelectric materials. These efforts became the basis for research and development being carried out today.

Cutting-Edge CMOS Sensors

Capturing

Images Even in the Dark

In order to develop an ultra-high-sensitivity multipurpose camera, Canon drew upon its optical technologies, cultivated through its digital SLR cameras, to realize an ultra-high-resolution and ultra-high-sensitivity CMOS sensor.



Moonbow captured at 55-meter-high falls, Niigata Prefecture, Japan

[Ultra-High-Sensitivity 35 mm Full-Frame CMOS Sensor]

A CMOS Sensor Capable of Clear Color-Image Capture by the Light of a Crescent Moon

From surveillance to observing natural phenomena, there is a growing need to capture video in the dark. Canon has developed an ultra-high-sensitivity sensor capable of Full HD video capture in color with reduced noise, even with minimal subject illumination—conditions under which subjects would be difficult to discern with the naked eye.

One way to better capture clear video images in low light is to enlarge the pixels on the CMOS sensor, increasing the amount of light each pixel is capable of receiving. In 2013, Canon announced the development of a prototype camera equipped with a 35 mm full-frame CMOS sensor for video capture. The sensor featured large-scale pixels measuring 19 μm (μm=micron, one millionth of a meter) square. Compared with the CMOS sensor incorporated into Canon's top-of-the-line EOS-1D X Mark II digital SLR camera, the pixels on this CMOS sensor have more than 7.5 times the surface area. In addition to enabling video capture in a dark room with no more illumination than that provided by burning incense sticks (approximately 0.05–0.01 lux), the ultra-high sensitivity 35 mm full-frame CMOS sensor also succeeded in capturing nighttime video (in an exceptionally dark shooting environment of less than 0.01 lux) of the Yaeyama-hime fireflies that inhabit Japan's Ishigaki Island.

Canon further refined the performance of the sensor and incorporated it into the ultra-high-sensitivity multipurpose camera, the ME20F-SH, which was launched in 2015 and is capable of capturing color video with a minimum subject illumination of less than 0.0005 lux, equivalent to an ISO sensitivity of four million (at maximum 75 dB gain).

In 2016 this multipurpose camera was used to successfully shoot video of a moonbow, a natural phenomenon rarely seen in Japan, using only the light of the moon.

Multipurpose cameras capable of operating in almost total darkness enable image capture in locations that are otherwise difficult to access. In addition to applications in disaster prevention and crime prevention, other possible uses include measuring instruments and industrial machinery, as well as the production of video of wild animals in their natural habitats.

ME20F-SH

Comparison of images captured under identical conditions

Shot by comparable professional-use video

Shot by the ME20F-SH, Canon's ultra-high sensitivity multi-purpose camera

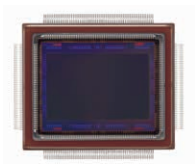
[Ultra-High-Resolution 250 Megapixel CMOS Sensor]

CMOS Sensor Can Identify Lettering on Aircraft Fuselage 18 km Away

Canon was quick to launch R&D efforts on CMOS sensors as far back as the 1990s. In 2010, the company produced a CMOS sensor with 120 megapixels, achieving a level of resolution equivalent to that of the human eye, a feat that garnered considerable attention. In 2015, Canon successfully developed an APS-H-size CMOS sensor with approximately 250 megapixels (19580 x 12600 pixels), the world's highest pixel count for its size. This ultra-high-pixel-count CMOS sensor achieves a level of resolution that is approximately 125 times that of Full HD (1920 x 1080 pixels) video and approximately 30 times that of 4K (3840 x 2160 pixels) video.

Despite the compact pixel dimensions, sensitivity was maintained by creating a structure that maximizes the amount of light captured. Though increases in pixel count results in increased signal volume, which can cause signal delays and timing discrepancies, an ultra-high-speed signal readout of 1.25 billion pixels per second was achieved through circuit miniaturization and enhanced signal-processing technology. Accordingly, the sensor is capable of capturing ultra-high-pixel-count video at a speed of five frames per second.

* As of December 31, 2017. Based on a Canon survey



CMOS sensor with approximately 250 megapixels

Image captured with a prototype camera equipped with an EF 800 mm telephoto lens using digital zoom. The image was digitally enlarged, and additional image processing was applied. The resulting image enables the identification of lettering on the fuselage of an airplane 18 km away, beyond impossible for the human eye.

New Product **CMOS Sensor with Global Shutter**

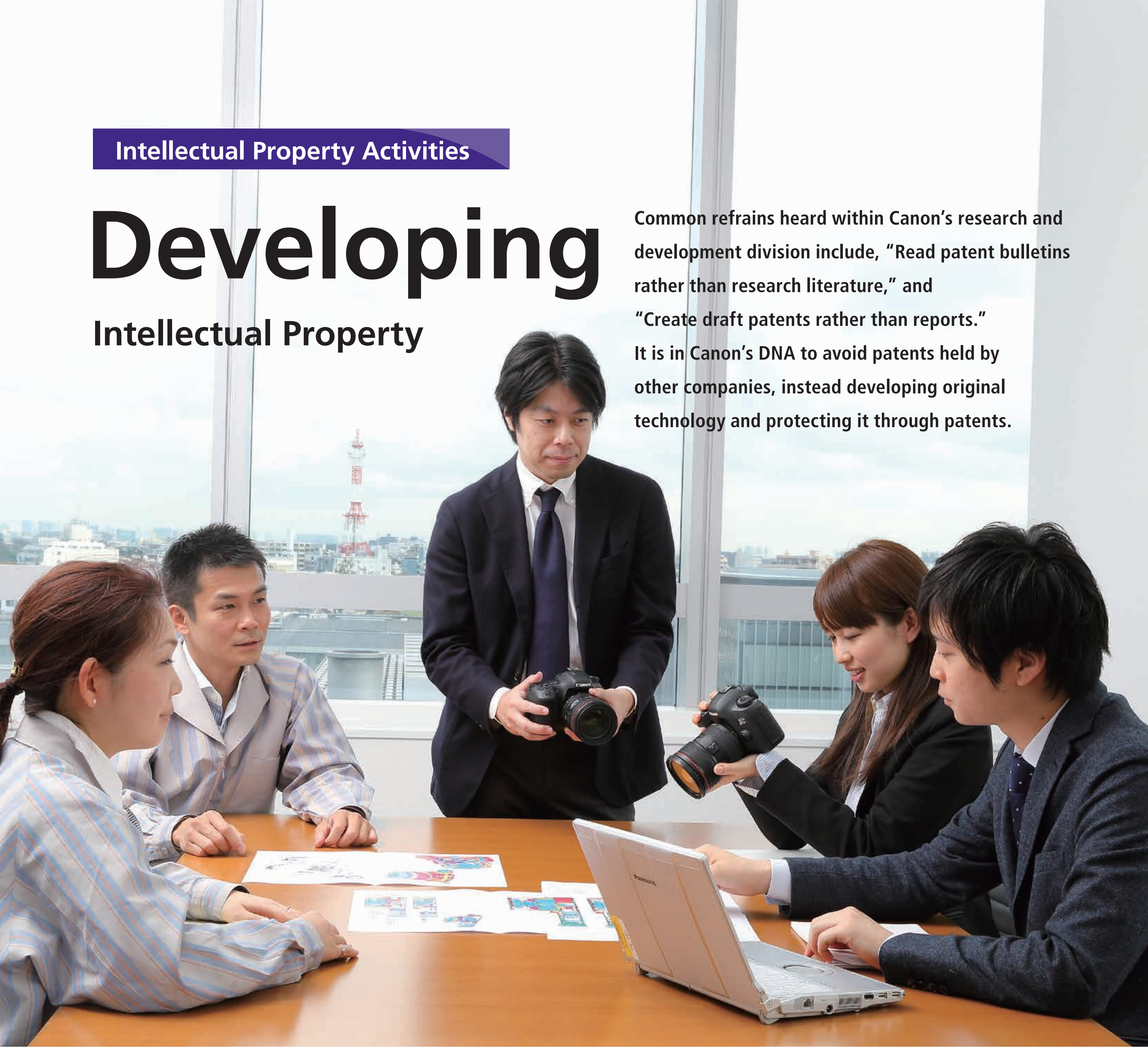
Canon has developed a global shutter-equipped CMOS sensor for industry, instrumentation and film production. This new CMOS sensor not only offers improved sensitivity and noise reduction, but by reading the data from the sensor's pixels at one time, it eliminates the "rolling shutter" effect, a distortion caused by taking in data from fast-moving subjects line-by-line.

Scan to access a special video and learn more about Canon's cutting-edge CMOS sensors

Developing

Intellectual Property

Common refrains heard within Canon's research and development division include, "Read patent bulletins rather than research literature," and "Create draft patents rather than reports." It is in Canon's DNA to avoid patents held by other companies, instead developing original technology and protecting it through patents.



Canon in the Top 5 Among U.S. Patent Recipients for 32 Consecutive Years and Top Japanese Company for 13 Years Due to Proactive IP Activities

Canon believes that acquiring patent rights for its proprietary technologies is an essential and important aspect of expanding operations globally.

Every year, Canon engineers submit more than 10,000 ideas with patent applications filed by country and region. In the United States, Canon has been the top-ranked patent recipient among Japanese companies for 13 straight years.

There are two aspects to Canon's intellectual property strategy. The first is defensive—to protect Canon's proprietary core technologies from being infringed upon by others. The second is offensive—to create advantages for Canon's operations by acquiring multiple patents that other companies, not just Canon, need to use, and then negotiating licenses for their use. Canon strengthens its product development capabilities through both defensive and offensive intellectual property management.

Number of U.S. Registered Patents Figures tabulated by Canon

Year	Rank overall	Rank among Japanese companies	No. of patents
2017	3rd	1st	3,285*
2016	3rd	1st	3,665*
2015	3rd	1st	4,134
2014	3rd	1st	4,048
2013	3rd	1st	3,820
2012	3rd	1st	3,173
2011	3rd	1st	2,818
2010	4th	1st	2,551
2009	4th	1st	2,200
2008	3rd	1st	2,107
2007	3rd	1st	1,983
2006	3rd	1st	2,366
2005	2nd	1st	1,829

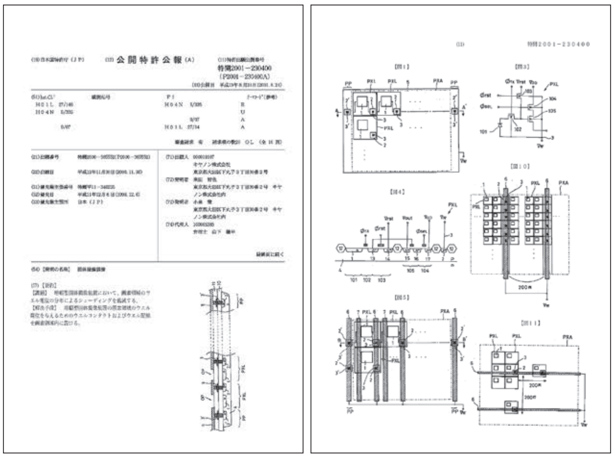
Based on annual information issued by the U.S. Department of Commerce

* Figures for 2016 and 2017 taken from IFI Claims Patent Services

Patent Strategy to Tackle Xerox's Monopoly

Canon's emphasis on intellectual property rights dates back to the 1960s, when the company entered the copying machine market.

In order to break through the airtight patent wall that U.S.-based Xerox had erected for its copying machines, Canon succeeded in developing the NP method, an all-new electrophotographic technology that did not infringe on Xerox's patents. Canon obtained a patent for the NP method. By protecting the differentiated proprietary technology, and also acquiring patens for peripheral technologies, Canon put itself in the position to be able to negotiate license agreements for other companies' technologies that Canon needed. This experience created the foundation for Canon's intellectual property strategy and has been passed down through the generations as part of Canon's corporate DNA.



Actual application submitted for patent bulletin publication (excerpt)

Engineers Work Closely with Patent Engineers to Cultivate Ideas

One major characteristic of Canon's intellectual property strategy is the active exchange of communication between engineers and patent engineers, who are in charge of intellectual property. Some 300 patent engineers at Canon operation sites throughout Japan examine new ideas and the research results of engineers from various angles, searching for ways to maximize the number of inventions that can be generated.

Basic Policy of Canon Intellectual Property Activities

- Intellectual property activities are vital to support business operations
- The fruits of R&D activities are products and intellectual property rights
- Other parties' intellectual property rights should be respected and attended properly

Collaborations with Global Companies

In this day and age, where cars are equipped with multiple cameras and some 100,000 patents exist for smartphones, it has become increasingly difficult for Canon to protect its technologies on its own.

In a move to assert the company's legitimacy and circumvent international patent disputes, Canon signed a cross-licensing agreement* with Microsoft in July 2014. Furthermore, with the aim of reducing patent litigation risks involving Patent Assertion Entities (companies specializing in filing patent-related lawsuits aimed at collecting licensing fees), six companies, including Canon and Google, established the License On Transfer (LOT) Network. As of December 2017, 192 companies have joined as members. In this way, Canon is working to coordinate with other companies to strengthen its competitive edge internationally through intellectual property.

* In a cross-licensing agreement, patent-right holders (companies, etc.) grant a license to each other permitting the use of a patent or patents held by the other party.

History of Awards for Canon Inventions

Several Canon inventions have often been awarded Japan's National Commendation for Invention (sponsored by the Japan Institute of Invention and Innovation), presented in recognition of inventions of great merit in Japan. Through the establishment of an internal Commendation for Invention system, Canon gives special recognition to the efforts of engineers and other meritorious individuals for their outstanding inventions.

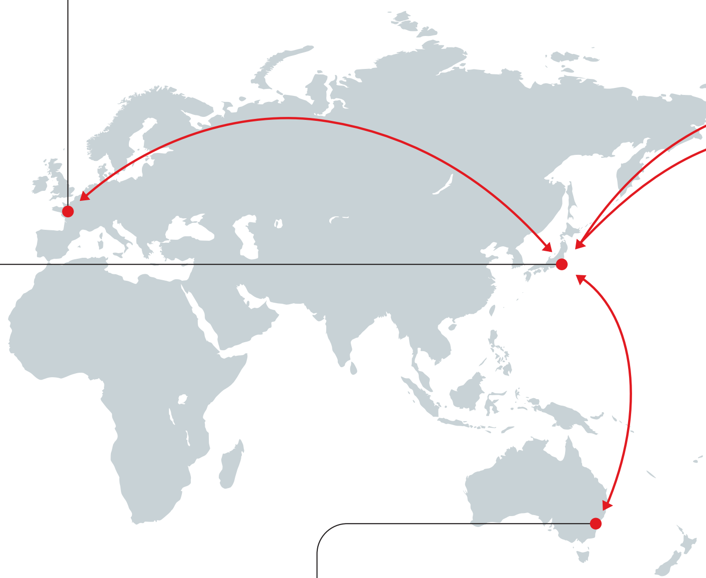
History of Canon's Receipt of Special Prize, National Commendation for Invention and Internal Invention Awards over the past 20 years

Name of Invention	Special Prize, National Commendation for Invention, sponsored by the Japan Institute of Invention and Innovation		Internal Invention Award	
	Year	Name of Award/Prize	Year	Name of Award/Prize
Invention of shading-reduction technology for CMOS sensors	2015	The Prize of The Chairman of Japan Business Federation	2005	President's Incentive Award
Design of a compact, lightweight digital cinema camera with outstanding mobility	2014	The Prime Minister Prize	2013	President's Award for IP Achievement
Invention of a printer using intermediate transfer member, without a cleaning mechanism	2013	The Prize of The Minister of Education, Culture, Sports, Science and Technology	2004	President's Award for IP Achievement
Box-shaped inkjet printer	2006	The Asahi Shimbun Prize	2005	President's Award for Excellence
Large-area sensor for real-time digital radiography system	2005	The Imperial Invention Prize	2001	President's Award for Excellence
Invention for a small-size optical system capable of high-speed zoom	2003	The Asahi Shimbun Prize	2004	President's Award for Excellence
Slim flatbed scanner design	2002	The Prize of The Chairman of Hatsumei Kyokai (JIII)	2001	President's Award for IP Achievement
Ozone-less charging method	1999	The Prize of Commissioner of the Japan Patent Office	1991	President's Award for Excellence
Invention of active type distance measuring device	1997	The Asahi Shimbun Prize	1996	President's Award for IP Achievement

Global R&D

The Canon Group conducts business in more than 220 countries and regions around the world. Today, sales outside of Japan account for more than 80% of Canon's consolidated net sales. To ensure that the research work from Canon's global R&D locations expands into businesses, the Canon's developers actively collaborate with and engage in exchanges with external research institutes.

Canon Research Centre France S.A.S.
Rennes, France
Research themes: Wired & Wireless communications, video transmission, video coding, and video surveillance
Research: Development of network and communication technologies, video data processing & coding technologies, and multi-camera system technologies, with International Standard contribution

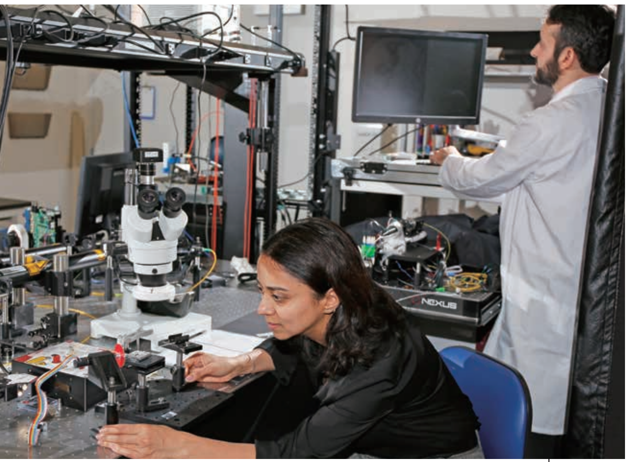


Canon's R&D Sites in Japan

Headquarters		R&D Areas Development of digital cameras, etc.
Yako Office		Development of inkjet printers, large-format printers and inkjet chemical products
Kawasaki Office		R&D Areas R&D on production equipment and dies; R&D on semiconductor devices, etc. Network camera development
Tamagawa Office		Development of quality management technologies
Kosugi Office		Development of software for office imaging products
Hiratsuka Plant		Development of displays and micro devices
Ayase Plant		Development of semiconductor devices
Fuji-Susono Research Park		R&D in electrophotographic technologies
Utsunomiya Office	Utsunomiya Optical Products Plant	Development of semiconductor lithography equipment and FPD lithography equipment
	Optics R&D Center	R&D in optical technologies
Toride Plant		R&D in electrophotographic technologies

* Medical devices are developed at the Kosugi Office, Canon Medical, and other locations.

Canon Information Systems Research Australia Pty. Ltd.
Sydney, Australia
Research themes: Image information processing, graphics
Research: Software and hardware R&D



Healthcare Optics Research Lab. (Canon U.S.A.)
Cambridge, Massachusetts
Research themes: Biomedical optical imaging, medical robotics
Research: Development of an ultra-miniature endoscope and needle-guiding system that employ micro-optical processing technologies, diffractive optical element simulations, and optical design technologies

Canon BioMedical, Inc. Rockville, Maryland
Research theme: Genetic testing
Research: Development of genetic testing equipment, reagent cartridges, etc., that employ CMOS sensor and inkjet printer technologies

Three Regional Headquarters Management System: Aiming to Create New Business Sectors

Aiming to expand the company's innovation centers, which are responsible for cultivating business domains, beyond just Japan to include Europe and the United States, Canon is working toward the establishment of a Three Regional Headquarters management system. Canon aims to leverage the characteristics and capabilities unique to these three regions—Japan, the U.S. and Europe—undertaking basic research, applied research and other R&D to create new businesses in the future.

In the United States, Canon's Healthcare Optics Research Lab (HORL) conducts collaborative research with Harvard-affiliated medical institutions on applied optical technologies for the medical field. Additionally, in 2015, Canon U.S.A. established Canon BioMedical to develop new businesses in the life sciences and genetic testing, strategically employing and linking together Canon's existing and new technologies.

In Europe, Océ is developing technologies in collaboration with Canon in Japan that involve ink and processes for commercial printing.

Working out collaborative details

Industry-Academia Alliances Pursue Cutting-Edge Optical Technology through Collaborative Research

To strengthen its research and development, Canon is bolstering ties with universities. In 2007, the company jointly established the Center for Optical Research & Education (CORE) in Japan with Utsunomiya University to support optical engineer training and research on state-of-the-art optical technologies.

In 2015, Canon joined the Japanese government's Impulsing PAradigm Change through disruptive Technologies program (ImPACT) to verify the clinical value of photoacoustic equipment developed in collaboration with Kyoto University. Canon will continue promoting joint research with universities and research organizations in Japan and abroad across a wide spectrum of domains aimed at advancing and commercializing science and technology.

Study-Abroad Program at Overseas Universities Improves Language Skills and Technical Abilities

Since 1984, Canon has offered its engineers a study-abroad program as part of it global R&D efforts, aiming to nurture international engineers and acquire technologies that will play a central role in Canon's future.

Engineers who participate in this program study cutting-edge or specialized technologies for two years at a university overseas. To date, more than 90 Canon engineers have studied abroad at more than 40 universities, including the Massachusetts Institute of Technology (U.S.A.), Carnegie Mellon University (U.S.A.) and the University of Cambridge (U.K.).

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