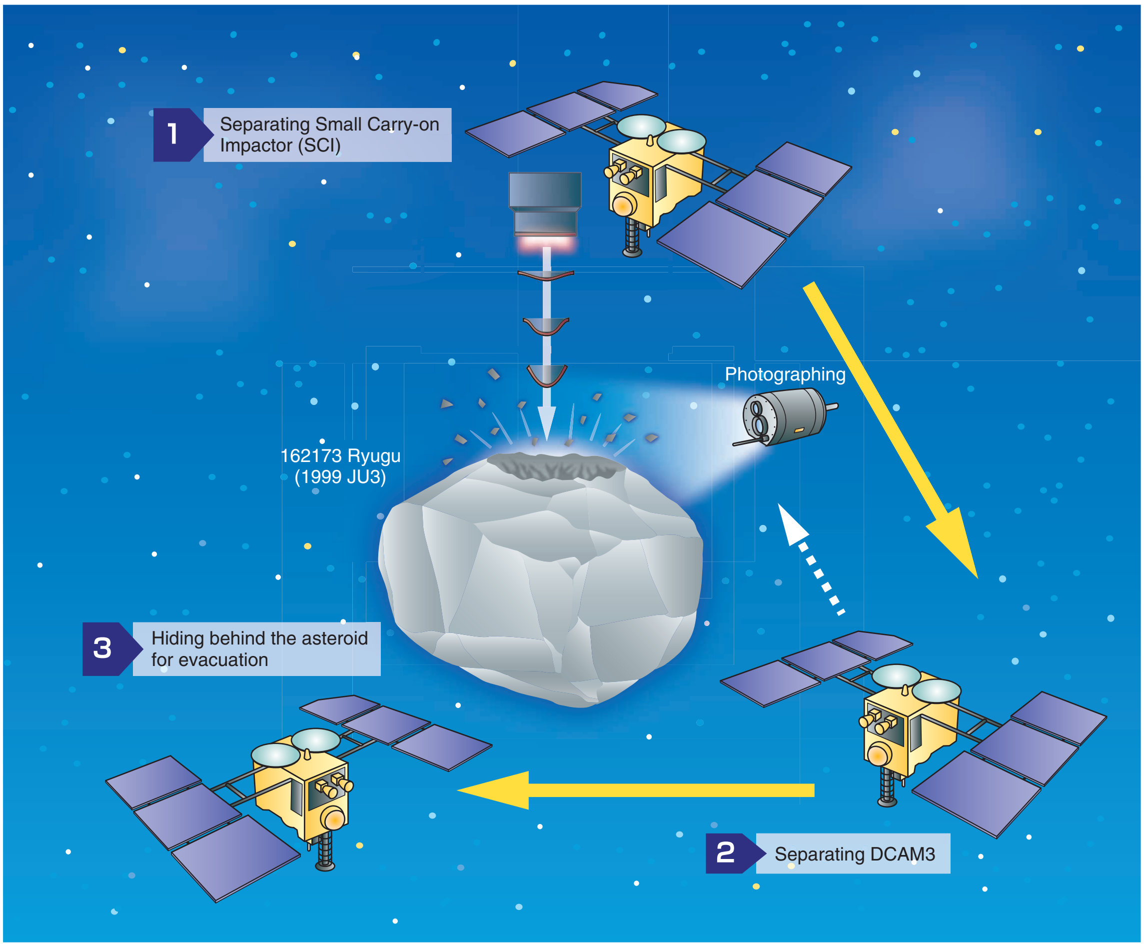
Take Pictures of the Crucial Moment of the First Blow against the Asteroid!

Commercial Off-The-Shelf (COTS) parts realized the DCAM3 deployable camera with ultra-high performance, low cost and short delivery time.

The asteroid spacecraft "Hayabusa" returned to the Earth after overcoming many unexpected difficulties. We still recall the day when it returned to the Earth safely. Meanwhile, on just December 3, 2014, "Hayabusa2" was successfully launched on the H-IIA rocket. "Hayabusa2" includes three pieces of equipment which we developed, and DCAM3 we introduce here is one of them.



Deployable DCAM3 mission image

DCAM3 takes pictures of the moment when SCI makes a crater

"Hayabusa2" is currently under flight on the way to asteroid 162173 Ryugu (1999 JU3), in an orbit slightly closer to the sun than Mars. Its main mission is to reach the asteroid for exploration, the same as the previous "Hayabusa," and to bring back samples. Asteroid 162173 Ryugu (1999 JU3) is an asteroid of a different type than Itokawa, having previously been explored, and 162173 Ryugu (1999 JU3) is believed to consist of more organic matter and moisture than Itokawa. By collecting and analyzing the material, the JAXA (National Research and Development Japan Aerospace Exploration Agency) team is expecting to clarify the origin of water and how the organic matter which constitutes lifeforms was created.

The most noteworthy point is that the material will not be collected from the surface, which is weathered by the space environment, but from the inside of the asteroid. The material from the inside is fresh and remains the same as that created at the birth of the solar system. The developed method was to make an artificial crater by impacting the Small Carry-on Impactor (SCI) against the surface of the asteroid and then collect samples from the surface. The main role for DCAM3 is to photograph SCI at the moment of collision with the asteroid.

The procedures are outlined as follows. When "Hayabusa2" approaches the asteroid within a certain distance, SCI will be released. As the next step, it will also release DCAM3 at a distance of about 1 km from SCI. After these two pieces of equipment are placed in space, the mother ship "Hayabusa2" will hide behind the asteroid for evacuation. After a certain period of time has passed, SCI will fire a projectile toward the asteroid by detonating about 5 kg of explosives and subsequently a crater with a diameter of up to about 10 m will be made. The mission of DCAM3 is to take high-resolution pictures of the moment when SCI collides with the asteroid and the topsoil will be blown off the surface of the asteroid after the collision.

DCAM3 cleared the payload problem of an unanticipated additional hi-resolution camera

DCAM3 will automatically be turned on a few minutes before the collision experiment. For one hour after SCI fires, it will take continuous high-resolution pictures at one second intervals with the projectile, 1 km away from DCAM3, fit into 4 pixels. Subsequently, DCAM3 will continue photographing at low resolution until its battery runs out. This image data will be compressed and transmitted wirelessly to the mother ship "Hayabusa2." The mission is completed when the battery runs out.

When the "Hayabusa2" project started, the mission was only taking pictures of situations, and very high-resolution was not required. Therefore, a low-resolution (analog) camera by another manufacturer was scheduled to be deployed. As the project proceeded, an idea came up where analysis of the image data obtained by a high-resolution camera enable to observe the behavior of the blowing off, i.e. the geometry of the ejector curtain, precisely. The objectives to be achieved are ① to clarify the physical structure of the surface layer of the asteroid, ② to understand the physical mechanism and the scale law of the crater formation, and ③ to identify the location of the collision. Therefore, despite the fact that the deployment positions for other devices, including the analog camera, had already been decided, a digital camera with another lens and wiring had to join in DCAM3. Including this addition, we were in charge of manufacturing this digital camera and developing a computer program for the compression of the image data and a system for transmitting data to the mother ship "Hayabusa2" (including a system for receiving data on the side of the mother ship and a system for storage in memory).

In spite of joining the project late, we achieved it within two-thirds of the delivery time

There were three challenges for development. The first challenge was to arrange the devices in a limited space. Since the deployment position of the analog camera was already decided, it was very difficult to install the digital camera in a limited space. It was essential to manufacture a more compact digital camera system with small parts and arrange the digital camera in DCAM3 more effectively. The second challenge was to meet the requirements for the data communication system. The specifications required a data transfer rate of up to 4 Mbps over a distance of 10 km, where the mother ship "Hayabusa2" would be located, and of up to 1 Mbps over a distance of 10-20 km. In the beginning, it was uncertain whether we could meet these requirements. The third challenge was to meet the production deadline. The system had to be completed in two-thirds of the production period normally required.

We participated in the project in the summer of 2012. The manufacturers in charge of other equipment had already participated in the Preliminary Design Review (PDR), produced an Engineering Verification Model, and were trying to start designing its details (flight model design). We joined midway through the project already in progress. It was a matter of course that the delivery time was the same as the other manufacturers who had been involved from the beginning. This project required that we would finish manufacturing the products meeting the specifications within a period of less than two years up to March 2014.

User-friendly and attentive service based on many years of achievements

DCAM3 came to have to hold additional payloads: a digital camera, a data compression device, a transmitting device, an antenna, battery, and electronic circuit boards. The first challenge was space arrangement. Because an analog camera had already been decided to be placed on the DCAM3 earlier and occupied space, the remaining space was very limited. First of all, we collected the necessary parts capable of enduring the space environment, drew circuit diagrams, and placed those parts on a PCB (Print Circuit Board) assembly drawing for mounting. Since high-resolution was the most important requirement, the combination of a lens and a 3.5 mm-square sensor could not be changed. The circuit for transmitting via radio waves had to be placed near the antenna. The IC (Integrated Circuit) performing extensive image processing needed enough space to provide high performance. When we failed to mount all of the parts on the drawing, we went back to searching for suitable parts again. We saved more and more space for mounting circuit boards and wiring and continued looking for suitable parts.

Most parts used in space exploration have been developed originally for defense purposes considering reliability. They are robust, but sometimes not compact, so they are not suitable to be mounted in such a limited space. We decided this time to select suitable parts from COTS (consumer products) taking into account the radiation resistance and other particular conditions, and had to make good use of technology for mounting electronic circuits capable of being used in the space environment.

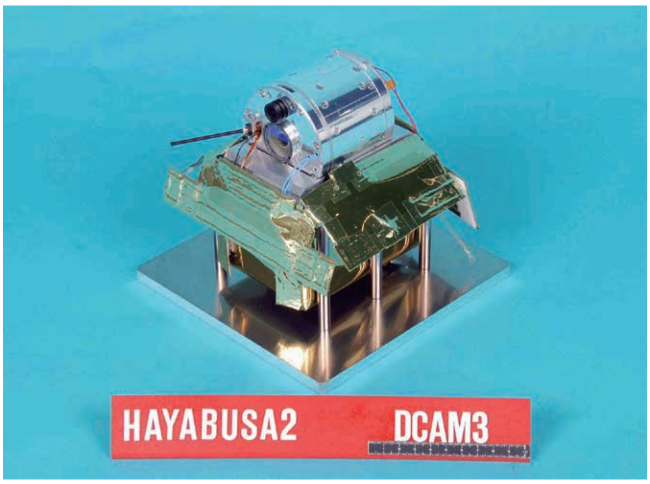
Sometimes in space, impulsive radiation with a large amount of energy could arise, which causes unexpected circuit malfunctions. The breakdown of the electric insulation caused by the radiation might result in critical damage to the IC. Cosmic radiation leads to white spots or pixel defects on image sensors. In addition, unnecessary outgassing could be released from the plastic materials used as shields in the vacuum. It is important to select plastic materials which will not release such gas.

As a result of the preliminary test of the communication function, it was found that the sensitivity was unsatisfactory on the receiver side, and stable data transmission was difficult to send over a distance of 10 km. Image processing also brought some trouble. We needed some work to solve these problems and meet the requirements by slightly increasing the electric power of receiver side.

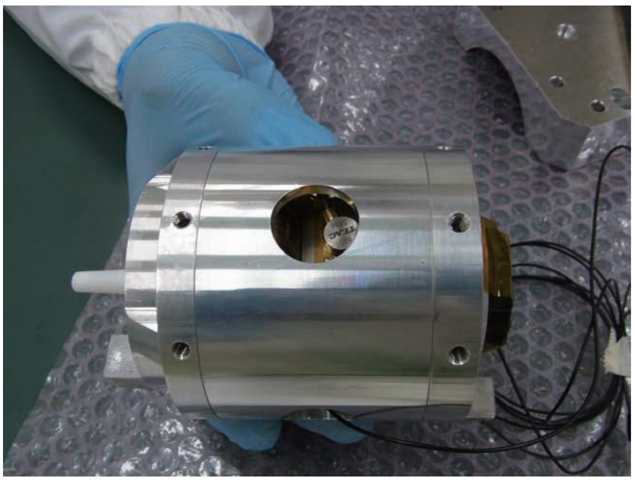
One of the factors that helped us to overcome the various difficult conditions was our relationship of trust with the JAXA. The advantages of our imaging technology, including our lenses and image processing, have been verified by the lunar orbiting satellite “Kaguya” (Selene), after having photographed the lunar surface with our high-definition camera. We had yet to truly experienced business in data transmission technology for space exploration, but had been involved in the telephone, radiosonde and defense businesses. These achievements might have formed the basis of our relationship. We have been manufacturing cost-effective products that meet detailed requests. Our user-friendly and attentive service has come to be well known among customers. They have also come to say, “Ask MEISEI ELECTRIC CO., LTD. (MEISEI) first to study about space-related imaging technology.”

We will sincerely meet niche needs for space-related products

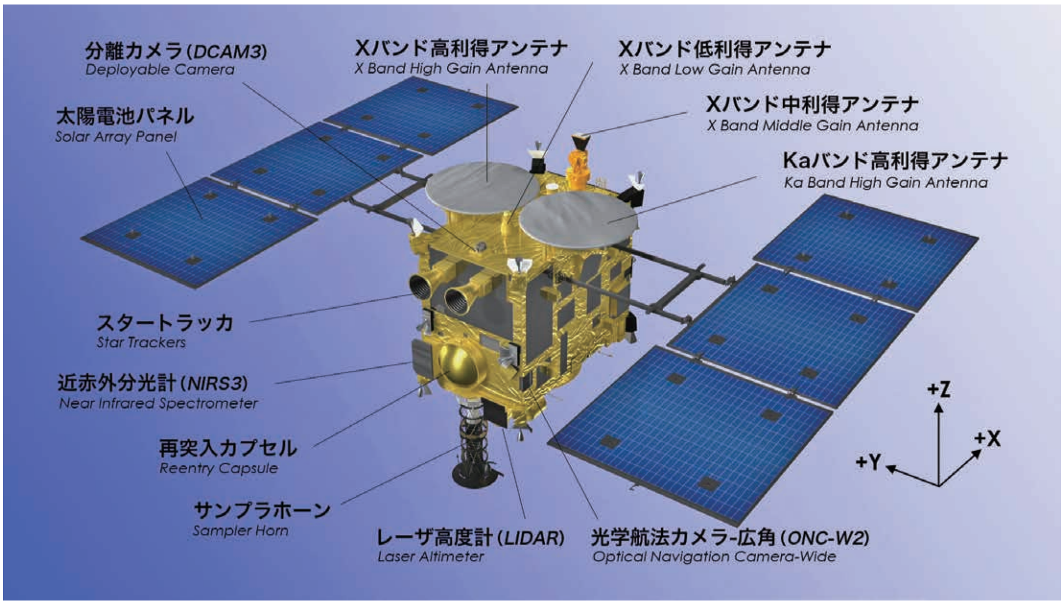
Honestly speaking, there is no unique technology of MEISEI that is not possible for other companies to possess. DCAM3 includes CMOS (Complementary Metal Oxide Semiconductor) or CCD (Charge-Coupled Device) image sensors. We selected devices with radiation resistance after testing. The CMOS adopted this time does not have the highest radiation resistance, but it is small in size and capable of being operated at less power. It is one of the semiconductors being used in commercial digital cameras, and we purchased it just as a spare part. But we have developed a proprietary technology to transmit the image data from image sensors to the mother ship after compressing it. Our advantage might be the ability that we can select the parts most suitable for space specification from among COTS parts. Our own technology



Separation Camera DCAM3 ©JAXA



Mock-up chassis including a digital camera for vibration testing



Configuration of "Hayabusa2" ©JAXA

might be our accumulated knowledge, such as the method of testing to select suitable parts.

When we are asked to supply compact and high performance products in a limited time, we adopt COTS parts with the permission of JAXA.

We tested a variety of parts in the past. This experience allowed us to grasp the general trend of every manufacturer and parts. Whenever we need detailed information, we can communicate directly with suppliers through close routes already established to select the appropriate parts. Of course, some parts are manufactured in our company. Obtaining proper assembly parts flexibly from COTS allows us to achieve high-spec products, favorable costs, and short delivery times. We are in a very niche market. However, end-user needs certainly exist. Our ability will be shown through meeting their needs. DCAM3 clearly showed the validity of this method.

Even when "Hayabusa2" successfully arrives at the asteroid in 2018 and takes photographs of the impact experiment using DCAM3, it will still take one or two years before we can see the photographs from the spaceship. "Hayabusa2" will exchange various data with the Earth, and the image data will be transmitted during these busy periods of communication. Therefore, we are afraid that will require considerable time to transmit the data even though it is compressed. We hope for fruitful success after successive efforts to overcome the difficult problems of development. We will await the arrival of the image data and the return of "Hayabusa2" to the Earth in 2020.

Mini commentary

COTS parts

The devices and parts used in the aerospace and military-related industries are usually custom-made products. To reduce costs and shorten delivery times, some manufacturers have come to actively use parts from consumer products, which are known as COTS parts, to meet requirements. They also have recently come to use such parts in industries that handle many custom-made products. One of the most important factors is the capability of evaluating quality and selecting parts.

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