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Creation of Fluid Art “Sound of Ikebana” under Weightlessness Using Parabolic Flight

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Abstract

New art in the future space age is an exciting subject. The authors, led by an artist, have been creating video artwork "*Sound of Ikebana*," made by applying sound vibration to fluid and shooting it with a high-speed camera. To study its shape under zero-G, we experimented with generating the artwork under weightlessness realized by parabolic flight. We confirmed that a new shape significantly different from the one created under normal gravity is created. Furthermore, a three-dimensional artwork was created by shooting the phenomenon from multiple viewpoints.

New Art in the Space Age

Recently, there have been many topics related to space; NASA's landing of an uncrewed spacecraft on Mars in February 2021 [1], Virgin Galactic's Richard Branson and Amazon's Jeff Bezos flying to an altitude of approximately 100 km in July 2021, a four-day flight to orbit around the earth by four civilians in SpaceX's spacecraft Crew Dragon in September

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2021 [2]. This means that space travel is becoming a reality fifty years after humans first land on the moon.
Although it is still a long way off for ordinary people to routinely travel into space, it is necessary to consider our life and society when space travel becomes as common as air travel. Art has been deeply linked to human spirituality since ancient times [3], and many artists were fascinated by the relationship between art and the universe. What art will look like in the space age is one of such relationships and an essential and exciting theme [4]. There are various factors characterizing the space age. Among them, weightlessness is one of the essential factors. Therefore, what art will become under weightlessness is an exciting research theme in the interdisciplinary area between art and technology.

We have been interested in the fluid phenomenon, primarily the high-speed fluid, invisible to the naked human eye. Based on this, we have been producing fluid art [5] by using a high-speed camera led by an artist Naoko Tosa, one of the authors. Fluid behavior is significantly different in weightlessness than in normal gravity. Studying fluid art in weightlessness is exciting and essential. Based on this idea, we challenged the theme of what art will look like in the environment of weightlessness, which is peculiar to space travel.

This paper describes related activities focusing on "high-speed phenomenon and art" and "art and zero-G." Then we introduce the fluid art concept that uses the fluid phenomenon and the details of a representative fluid art called "*Sound of Ikebana*." Also, we will consider the relationship between the artwork and Japanese beauty. Then we describe the experiment process and the produced art, where the artist herself creates artworks under the weightlessness obtained by the flight called "parabolic flight." We also describe an attempt to create a 3D art object from the obtained 2D art video.

Related Activities

Art and high-speed phenomenon

Attempts to integrate art and technology are called "Art & Technology" and have been in progress for some time. The development of technology such as computers has recently advanced so fast, providing increased opportunities, and many activities are carried out [6] [7] [8]. Since people desire to see invisible things, attempts to visualize high-speed events using technology have been active.

A pioneer in this field is Harold Edgerton, once a professor at MIT [9]. He used the Electronic Flash to study the high-speed phenomenon and further developed it into the Stroboscope. His achievements are famous, such as taking a series of photographs of balloons exploding by shooting the moment when a bullet hits an apple. He is also well-known for his photographs of the milk crown, in which a milk drop creates a beautiful crown-like shape as it falls [10]. His invention, the Stroboscope, and photographs and films taken with it are exhibited at the MIT Museum and Edgerton Center [10] [11].

One of the authors, Naoko Tosa, stayed at MIT CAVS (Center for Advanced Visual Studies)

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as an Artist Fellow between 2002 and 2004. At that time, she often visited the MIT Museum and Edgerton Center. She was greatly inspired by the Stroboscope invented by Harold Edgerton and his works that visualized the high-speed phenomenon. This experience led her to visualize fluid phenomena in artworks using a high-speed camera.

Bill Viola is another well-known example of an art creator using a high-speed camera [12]. While Tosa pays attention to the natural fluid phenomenon, Bill Viola tries to express elements of human life, death, consciousness, etc., that exist at the foundation of human behaviors by expressing human movement in super slow motion.

Art and Zero-G

People have been fascinated by the universe for a long time and have created art about the universe. These arts are called "space art" [13]. Many attempts have been made to draw the universe as an art based on the artist's imagination and to draw the earth as seen from the universe. When the crewed flight to the moon and astronauts' stay at the space station became possible, attempts began to put art works on the spacecraft and send them to the space station and the moon. There are also some ideas for launching huge artwork that can be seen from the earth at the same altitude as satellites [14]. However, these have not been realized due to budgetary concerns.

Among these, as a movement to explore new art forms suitable for the space travel era, attempts have been made to create art under weightlessness, an environment peculiar to space travel. Such art is called "zero-G art."

A pioneer who created artwork in weightlessness is Frank Pietronigro [15]. In April 1998, he flew from the NASA Johnson Space Center aboard a turbojet airplane to create "drift painting" under weightlessness achieved by parabolic flight. A 75-inch high by 48-inch wide by 52-inch deep plastic bag was developed beforehand and was tethered to the jet's interior. In this "creativity chamber," he, while freely floating, projected various color paints into the space surrounding his body.

Another pioneer who created a 3D artwork in weightlessness is the Israeli artist Eyal Gever, who made a 3D printed artwork called “Laugh [16]” using a 3D printer on the International Space Station (ISS). In 2016, he and his team launched an app that converted the sound waves of users' laughter into a digital 3D model. More than 100,000 people generated their 3D models. The best one was selected by the vote of the app users, which was then 3D printed on the ISS.

The MIT Media Lab in the United States has launched the "Space Exploration Initiative [17]" to conduct various experiments under weightlessness. Among them is a project to explore art in the space age. For example, in a project called "Telepresent Drawings in Space [18]" conducted by an artist, the theme is how to deliver sensations and emotions in outer space to the ground. The trajectory of an object floating under weightlessness is recorded with sensors. They try to reproduce the trajectory on the ground and make it an artwork.

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In Japan, JAXA (Japan Aerospace Exploration Agency) has a Japanese laboratory called "Kibo [19]" on the ISS, which has been used for scientific experiments and art creation experiments. From 2008 to 20111, the first call for proposals for art creation in space was opened, and nine experiments were conducted in "Kibo" [20]. From 2011 to 2013, eight other themes were implemented in the second phase [21].

These studies are significant as pioneering research on new art in the space era. At the same time, there are only a few trials in which artists themselves tried to create artworks under weightlessness. In our project, like the art creation activity of Frank Piertronigro, an artist herself creates art under weightlessness.

Fluid Art "*Sound of Ikebana*"

Fluid art

The behavior of fluid consists, in large part, of natural phenomena. Water flow, wave behavior, ocean currents, etc., are typical examples [22]. Fluids are known to be able to create beautiful shapes under a variety of conditions, such as the milk crown mentioned earlier. As beauty is a fundamental element of art, it is natural to use fluid phenomena as a basic methodology for art creation. One of the authors, Naoko Tosa, has led a project to create "fluid art" by shooting the behavior of fluids with a high-speed camera. High-speed cameras have traditionally been used to capture a variety of phenomena that occur in a short period, such as the explosion of physical material. On the other hand, we were interested in producing various beautiful organic shapes using fluids. Then, we found it possible to create an Ikebana-like shape (Ikebana is a Japanese flower arrangement) with a fluid such as paint by applying sound vibration. Figure 1 shows the generation system. A speaker is placed facing up, a thin rubber film is put on it, a fluid such as paint is placed on the rubber film, and the speaker is vibrated with sound. Then the paint jumps up and makes various shapes, and the process is captured with a high-speed camera. Here, a high-speed camera of 2000 frames/second is used. A PC connected to the speaker produces various sounds that vibrate the speaker.

"*Sound of Ikebana*"

Using this environment, we systematically changed the shape of sound (sine wave, etc.), frequency of sound, type of fluid, the fluid's viscosity, etc., and shot various fluid forms with a high-speed camera [23]. We confirmed that various beautiful Ikebana-like shapes were generated. Tosa created a collection of video art called "*Sound of Ikebana* [24][25]" by editing the obtained video images according to the colors of the Japanese seasons. Figure 2 shows several scenes of the work. She used this work for projection mapping in Singapore in 2014. Also, in April 2017, as part of her "Japan Cultural Envoy" activities, she held an exhibition at Time Square in New York using more than 60 digital billboards.

Concept of the *Sound of Ikebana*

The Sound of Ikebana is an artwork based on fluid movement when vibrations with various frequencies are applied. Therefore, it is an art based on physical or natural phenomena.

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People generally understand that art is the embodiment of the beauty created by an artist. In that sense, the artwork is different from traditional art; therefore, its concept is essential. Naoko Tosa, one of the authors, was appointed as a Japan Cultural Envoy in 2016 to exhibit her artworks worldwide. Many people, including people involved in the art community, commented, "I feel Japanese beauty in her art." The question arises as to why people felt Japanese beauty in her artwork based on physical phenomena.

The *Sound of Ikebana* is made by giving sound vibration to liquid, but the artist controls the production process. By systematically changing the fluid's viscosity, frequency, volume, etc., the artist conducted various experiments to create the artwork. She learned what kind of shape was produced under what conditions and selected several specific conditions among them according to her sensibility. She also learned how much liquid to put on the speaker, what colors to select, etc. Then she edited the video to create the video art. This is similar to how an artist uses paints and paintbrushes to create artwork through trial and error. In other words, Tosa creates her artwork using sounds and fluids instead of paintbrushes and paints. Once the sound, the fluid, the color, etc., are decided, the shape created by the sound vibration is greatly influenced by chance. In that sense, this is an art production where the artist selects tools and adds the element of chance to them.

Such an art production method is similar to Jackson Pollock's. He is well known for developing an art-making technique called "action painting [26]," in which paint is dripped or thrown onto the campus instead of painted on campus with a paintbrush. In his case, the paint color and where to drop it on the canvas are carefully considered in advance. At the same time, the shape of the dripped or thrown paint is greatly influenced by chance. As mentioned earlier, Frank Pietronigro's art creation method called "drift painting [15]" is similar to "action painting." In addition, it is notable that Frank Pietronigoro achieved it under weightlessness.

One crucial point in both artworks is a balance between the artists' intentions and random chance. If a carefully crafted balance is achieved, people perceive and admire beauty in such artworks.

Another feature of Tosa's art production method is that she uses advanced technologies. The movement of the fluid vibrated by sound is swift, and the developed liquid form would, under normal circumstances, be too fleeting to be appreciated. The moment of beauty is captured only by shooting it with a high-speed camera. Therefore, it is an artwork that fuses art and technology; the artist decides the concept and production method, and technology supports the final work.

The *Sound of Ikebana* and Japanese beauty

When Tosa exhibited her artwork overseas, many people felt the presence of Japanese beauty in her art. Why did they feel like this? To answer this question, we try to explain what Japanese beauty is.

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People like Bruno Taut pointed out that Japanese artworks and architecture have always emphasized and expressed a sense of unity with nature [27]. In tracing this origin, we arrive at the idea of the so-called oriental monism. Oriental monism preaches the unification of humans and nature and is the basis of the philosophy of Laozi and Zhuangzi [28]. This suggests that beauty is already present but primarily hidden in nature and that some Japanese artists have found ways to reveal and draw focus to such hidden beauty.

The methodology of extracting the beauty hidden in physical and natural phenomena fits the traditional concept of Japanese beauty. Below are several examples showing the relationships between Tosa and traditional Japanese art.

Japanese artists have found beauty in natural phenomena such as rivers and scattered waves and have created artworks. Katsushika Hokusai's "The Great Wave off Kanagawa from Thirty-six Views of Mt. Fuji" (Fig. 3: left), which expresses the dynamic movement of the waves, has long been considered a typical expression of Japanese beauty and has had a significant influence on artists around the world [29]. Interestingly, this dynamic wave movement resembles the shape created in a fluid captured with a high-speed camera. Figure 3 also shows the form when we fired an air gun projectile into the water-paint mixture. The similarities between the two can be seen.

Another example of the similarities between the artwork and nature is the primary form of Ikebana [30]. The primary form of Ikebana is an asymmetric triangle that connects three points of different heights, "core," "sub," and "body" (Fig. 4: left). It is interesting to note that the shapes in the '*Sound of Ikebana'* often resemble the form of Ikebana (Fig. 4: right). Although, at this moment, we do not have evidence to justify such relationships, we are approaching this substantial issue from a scientific point of view [31].

Weightlessness Generation Method

There are two typical methods to realize weightlessness on earth.

Parabolic flight

Parabolic flight means flying on a parabolic flight path [32]. After gaining sufficient speed by a rapid descent, the aircraft is raised, and the thrust is narrowed down to the extent that it compensates for air resistance to perform the parabolic motion. A weightlessness environment of about 10^{-2}G to 10^{-3}G can be realized during the parabolic flight for about 10 to 20 seconds. One company in Japan provides commercial services for parabolic flights [33], which have been used for various weightless experiments and the training of astronauts. Figure 5 shows the flight curve in parabolic flight and the gravity in each phase.

Free fall

When an object falls while being pulled by gravity, it is weightless. In other words, weightlessness can be achieved by creating a free-fall state by dropping things from a high place.

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In Japan, the Micro-Gravity Laboratory of Japan (MGLAB) in Gifu Prefecture has a free-fall system with a distance of 100 m and a free fall time of 4.5 seconds. This drop tower is evacuated inside the tower to eliminate air resistance [34].

Also, the Bremen Drop Tower at the University of Bremen, Germany, is well known. Its height is 147m (actual fall distance is 110m), and when the falling capsule is dropped in a tower that has been evacuated, weightlessness for almost 4.7 seconds can be achieved [35].

Creation of Fluid Art under Weightlessness

Basic methodology

To create art under weightlessness, we worked on an experiment in which the artist took the initiative in creating the *Sound of Ikebana* under weightlessness. At the same time, in addition to shooting the image of the artwork under weightlessness and making it a two-dimensional video art, we attempted to realize it as a three-dimensional object. The artwork has often been recognized as "Japanese" [25]. Making the artwork into a three-dimensional object allows us to exhibit it to allow people to examine and consider the work from entirely new perspectives. It will then be possible to receive more total impressions and comments on why it resonates as “Japanese” to so many people. To pursue this idea, we tried to create the 3D shape of the artwork [36].

To realize 3D restoration, a method to create a 3D model based on images taken from multiple directions is being studied [37]. Multiple still cameras and multiple high-speed video cameras are used. Performing synchronous shooting using multiple still cameras can be used at a relatively low cost, but the timing of pressing the shutter becomes a problem. We first constructed a system using multiple still cameras and conducted various experiments. However, we found that it is challenging to obtain shooting results that are beautifully shaped depending on the precise timing of pressing the shutter. Based on the preliminary experiments, we decided to conduct an experiment in which shooting is performed using multiple high-speed cameras.

Art creation using parabolic flight

Creating the *Sound of Ikebana* during parabolic flight requires a small-size version of the generation system shown in Fig. 1 adapted for use on the aircraft. Furthermore, to make the artwork into a three-dimensional object, it is necessary to have a system equipped with multiple high-speed cameras. Figure 6 shows the developed generation system, which uses a high-speed multi-camera system. The camera part has 2M pixels and 2000 frames/second shooting speed. Six units were installed surrounding the speaker. For complete 3D restoration, it is necessary to shoot from 360 degrees. However, since a workspace such as setting paint is required, finally, we decided to use six high-speed cameras surrounding the speaker at about 120 to 180 degrees.

Creating the artwork during the parabolic flight requires quickly achieving all the necessary processes during a short period. All the participants in the experiment, including the artist

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Naoko Tosa, were new to parabolic flight. We installed the generation system in our laboratory to minimize failures in an unfamiliar environment and conducted training by simulating the actual flight. We practiced setting a new film on the speaker, setting paints on it, driving speakers, shooting in synchronization, and cleaning after shooting with the same time intervals as necessary during the actual flight. By practicing this about 30 times, it was possible to perform each procedure skillfully and in a short time. It was possible to create and shoot the *Sound of Ikebana* almost without failure by following the practiced procedure during the actual parabolic flight.

In parabolic flight, weightlessness was achieved about ten times. For each weightless experience, the duration was about 20 seconds. Figure 7 shows scenes during the flight.

Sound of Ikebana **under the parabolic flight**

One parabolic flight allowed us to experience weightlessness ten times. The flight was carried out twice over two days, and the artwork was created 18 times, with only two failures. Therefore, obtaining a video image of 6 positions x 18 times was possible. Figure 8 shows one example of how the images changed over time. Fig. 9a shows an image of a video taken from 6 positions at a particular moment.

We found that the *Sound of Ikebana* generated under weightlessness has the following characteristics compared to the same process conducted under normal gravity.

・Under gravity, the height to which the paint rises is somewhat suppressed. However, the paint can reach higher under weightlessness and create more extended shapes.

・Under normal gravity, the paint achieves a certain height, then starts to fall; thus, the resulting shape comprises both rising and falling paint. However, since falling does not occur under weightlessness, the created shape, extending itself more fully, looks more novel and sophisticated.

A more detailed and scientific comparison of the created forms under weightlessness and normal gravity will be carried out in future work.

Three-dimensional materialization of the *Sound of Ikebana* under weightlessness.

Various studies have created a 3D model from images from multiple viewpoints [37]. There is also some commercial software for these purposes. The obtained 3D model makes it possible to generate a 3D object with a 3D printer. An example of the completed *3D Sound of Ikebana* is shown in Fig. 9b.

At this stage, the created 3D artwork is still in its early stage. Also, the created form is incomplete, as the multiple high-speed camera units captured only the front side of the 360-degree form. Now we are challenging the restoration of 360-degree form using AI [38].

Conclusion and Future Prospects

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As the space age arrives, it is essential to consider new art in the new era. One of the authors, Tosa Naoko, has created a video artwork called the *Sound of Ikebana* based on the fluid phenomenon. We are interested in what shape this art would produce under weightlessness. We adopted parabolic flight to create weightlessness and conducted experiments on the art creation led by Tosa. Also, we were challenged to make the artwork as a 3D object by shooting the phenomenon using multiple high-speed cameras.

We found that the fluid expands dynamically and does not fall due to weightlessness. As a result, we obtained more sophisticated, beautiful, and organic artwork shapes under weightlessness than ordinary gravity. As a result, we have obtained new 2D and 3D arts that symbolize the "space-age."

One big problem with art creation using parabolic flight is that it is very costly and challenging to carry out the trial continuously. We found an alternative solution; fluid art creation in weightlessness using free-fall. Although it is difficult and costly to create long time (10 seconds or more) weightlessness, it is relatively easy to create short time (around 0.5 seconds) weightlessness by developing a simple free-fall system. Furthermore, fortunately, the creation of the *Sound of Ikeban*a occurs in a short time of less than one second. As a continuation of our fluid art creation using parabolic flight, we think art creation using free-fall would fit the art creation under weightlessness. We plan to go in this direction [39]. Based on such efforts, we plan to exhibit this new art as 2D and 3D art so that people can appreciate its original and organic shape. Furthermore, we consider using it for the shape of vehicles and architecture in the future society. Such new applications will be exhibited at the Osaka World Expo in 2025.

Acknowledgement
We thank Mr. Takao Doi, a former JAXA astronaut and now Visiting Professor at Kyoto University, for his valuable suggestions/support. We also thank NAC Inc. for lending us multiple high-speed cameras during the preparation and execution of the parabolic flight, especially to Mr. Yamamoto of NAC for his continuous support.

Figures

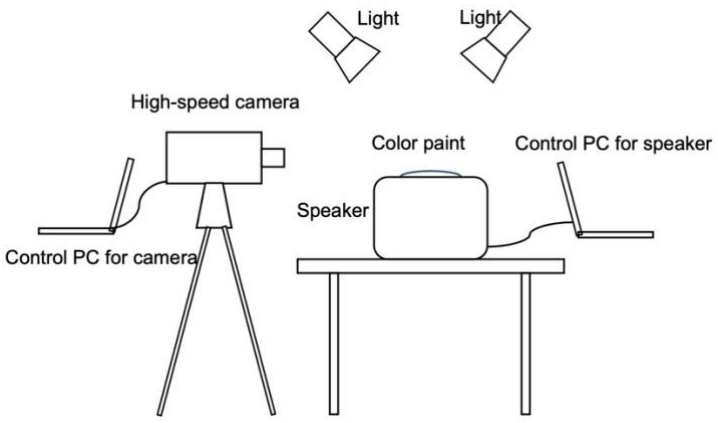

Fig. 1 Fluid art generation system. (©Naoko Tosa)

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Fig. 2 Scenes of the *Sound of Ikebana.* (©Naoko Tosa)

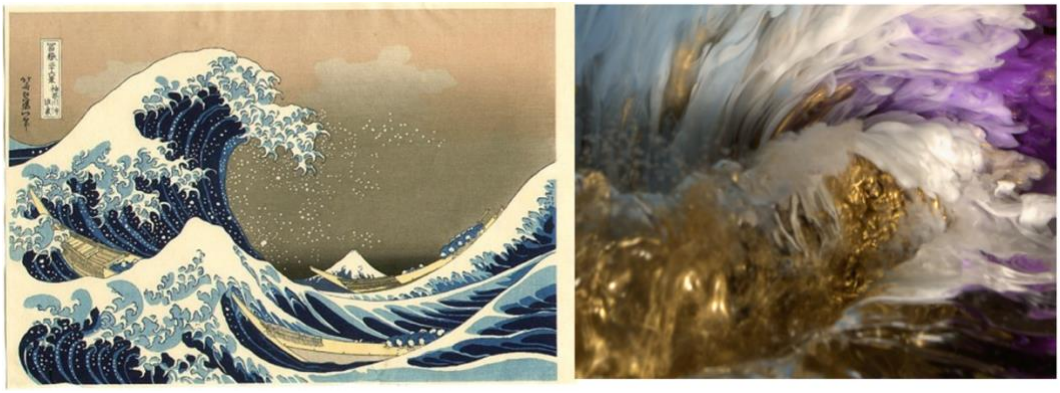

Fig. 3 left: Katsushika Hokusai "The Great Wave off Kanagawa from Thirty-six Views of Mt. Fuji." (in the public domain) right: Behavior of fluid captured by a high-speed camera. (©Naoko Tosa)

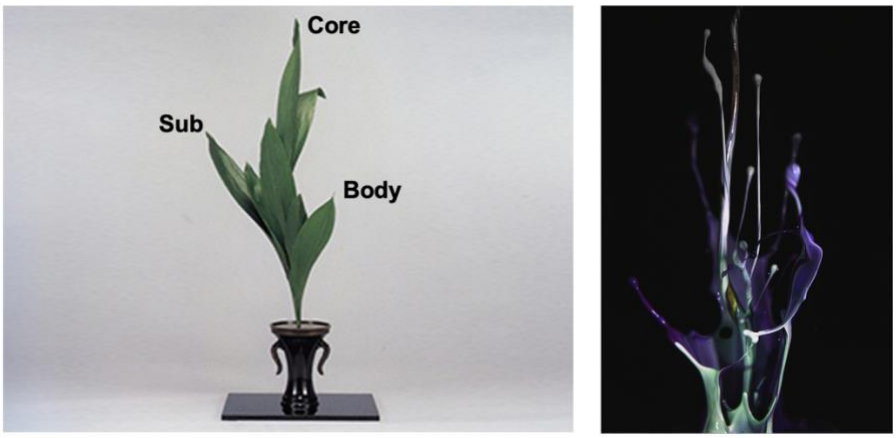

Fig. 4 left: The basic form of Ikebana. (in the public domain) right: A form of the *Sound of Ikebana*. (©Naoko Tosa)

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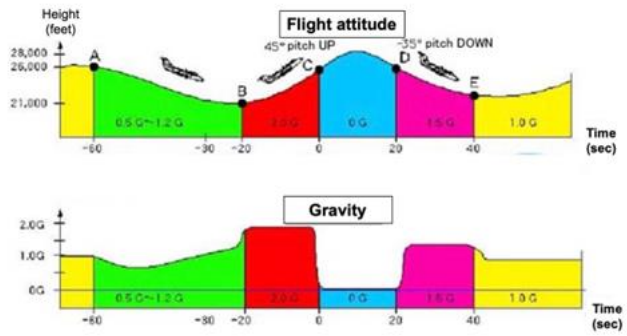

Fig. 5 Parabolic flight.

a. Front view

b. Side view

Fig. 6 *Sound of Ikebana* generation system for parabolic flight. (©Naoko Tosa)

Fig. 7 Scenes of the *Sound of Ikebana* creation during an actual parabolic flight. (©Naoko Tosa)

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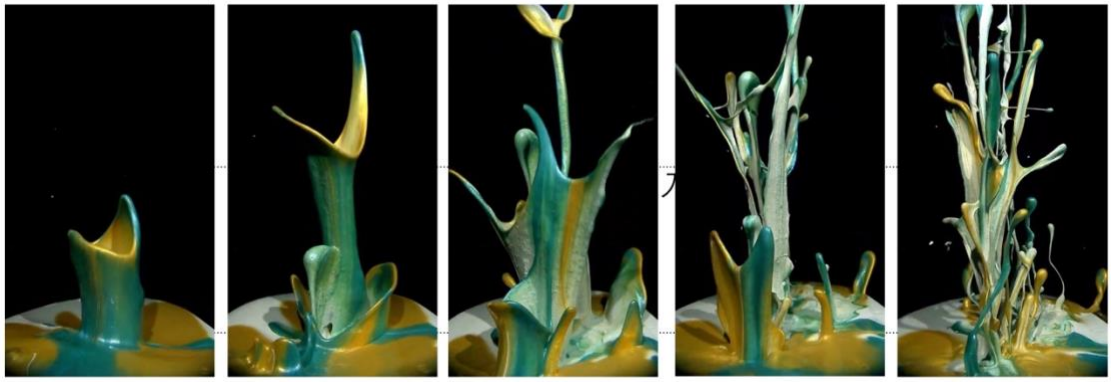
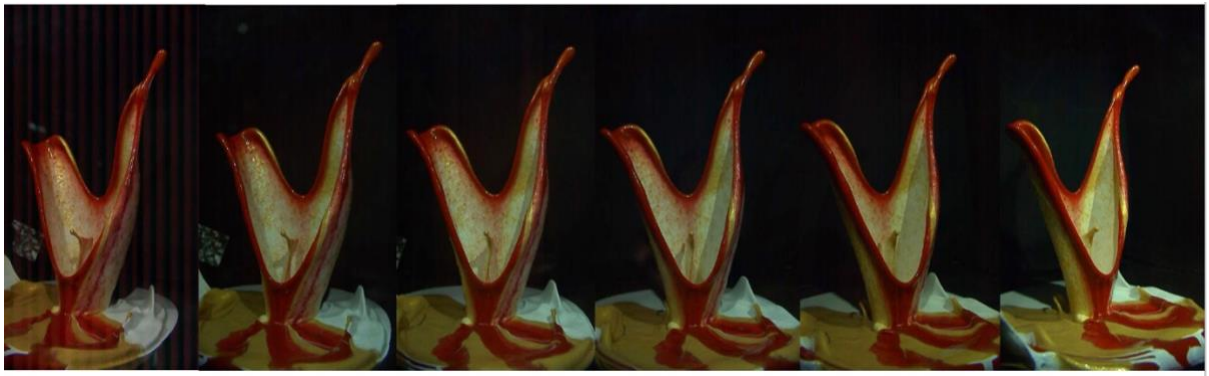


Fig. 8 An example of how the *Sound of Ikebana* changes its shape depending on time. (©Naoko Tosa)



a. An example of images shot from multiple positions.

b. An example of the *3D Sound of Ikebana* created by using a 3D printer.
Fig. 9 2D and 3D shapes of the *Sound of Ikebana* generated under weightlessness. (©Naoko Tosa)

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