Drone Light Shows Activation for the Olympic Games Tokyo 2020 Opening Ceremony

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Abstract

Intel Corporation was honored to be the Official Drone Light Shows Partner for the Olympic Games Tokyo 2020. As millions of viewers worldwide came together to watch the Opening Ceremony on July 23, 2021, thousands of Intel [Note 1] drones took to the skies above the Olympic Stadium. This was an unforgettable performance that celebrated the athletes' inspiring achievements and the triumph of the human spirit.

Keywords : Intel Drone Light Shows, Olympic Games Tokyo 2020 Opening Ceremony

1. Introduction

The breathtaking globe high above the Olympic Stadium (Figure 1) was an unforgettable moment from the Opening Ceremony of the Olympic Games Tokyo 2020. Intel launched 1,824 drones into the sky in a spectacular performance that began with the Olympics' Kabuki-inspired checkered emblem. As the emblem hung large in the night sky, it seamlessly transitioned into a blue and white orb before morphing into the now-iconic globe. While the stunning image of the world hovered over the stadium, John Lennon's beloved song "*Imagine*," arranged by Hans Zimmer, provided a heartfelt accompaniment. Sung by John Legend, Keith Urban, Beninese singer-songwriter Angelique Kidjo, Spanish performer Alejandro Sanz, and the Suginami Children's Choir, the rendition provided a stirring soundtrack to the performance that quickly became a social media sensation.
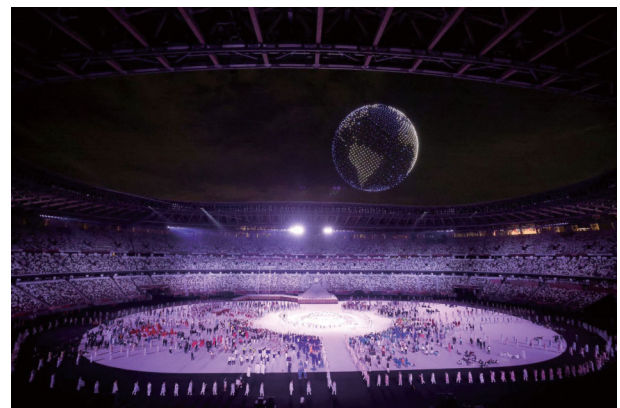

Figure 1　A globe, Performed by Intel Light Show Drones, Floated High above the Olympic Stadium during the Opening Ceremony of the Olympic Games Tokyo 2020（©2021-International Olympic Committee-All Rights Reserved）

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2. Intel Drone Light Shows Overview

Intel Drone Light Shows is an innovative form of art and storytelling, branding, or advertising. The sky becomes your largest canvas, billboard, or movie screen. This is a smoke-free and noise-free way for audiences to enjoy 3D animated stories and dynamic formations choreographed to music. There can be 100s/1,000s of pre-programmed drones flying in unison-all controlled by one pilot. Intel Drone Light Shows uses state-of-the-art technology. Designed specifically for light shows, Intel drones are lightweight, incorporate key safety features, and are engineered to be more tolerant of real-world performance conditions.

The innovative Intel launch pad simplifies shipping, storage, deployment, charging, launch, and auto-landing. Built to hold six drones each, the launchpad reduces airfield footprint, acts as a wireless communications hub for the drones during performances, and provides a stackable, secure, and robust transportation enclosure.

In addition to hardware, the customized performance control software developed by Intel enables a single computer to manage an entire fleet of up to 10,000 drones. From setting geofences to running fleet checks before flights, this robust software allows Intel to efficiently conduct safety and risk assessments, drone tracking, and regulation compliance.

3. Preparations for Drone Light Show Activation in Tokyo 2020 Opening Ceremony

3.1 Purpose-built Light Show Drones

Intel light show drones have dazzled audiences across the globe for years. For the Olympic Games Tokyo 2020, Intel built the next generation of light show drones. As a result, the Intel Premium Drone (Figure 2) was launched. The Intel Premium Drones are brighter, faster, and have improved positional accuracy for crisper animations. With four LEDs, their increased luminosity makes them perfect for settings with high ambient light, such as Tokyo (Figure 3). They also have an increased wind tolerance and require less air and ground space.

It was not only the technology that was required to perform a crowd-wowing light show experience during the Tokyo 2020 Opening Ceremony, but it also required a lot of advanced preparations in operations, infrastructure, art creation, and safety planning to deliver the spectacular drone light show experience.

Figure 2 Intel Premium Drone, a Purpose-built Drone for Light Shows（©2021-Intel Corporation）

Figure 3 Intel Premium Drone Luminosity with High Ambient Light in Tokyo（©2021-International Olympic Committee-All Rights Reserved）

3.2 Drone Light Show Design

During the initial design phase, safe flight areas, spectator positions, and optimal viewing angles were identified. At the same time, the Intel creative team, in close collaboration with the Tokyo 2020 Opening Ceremony team worked with sketches and storyboards to bring the show narrative and vision to life.

The logo of the Tokyo 2020 Olympic Games by TOKOLO Asao served as the basic concept for the first element of the drone show. The pattern TOKOLO used in these emblems was a nod to Ichimatsu Moyou, a traditional Japanese checkerboard pattern that became popular during the Edo period (1603-1867). While sending a message of unity and hope, the drones transitioned from the TOKOLO emblem into a Globe high above the Olympic Stadium highlighting the motto of the Olympic Games: Faster, Higher, Stronger-Together.

The drone show started with the Tokyo 2020 Olympic Games logo in the night sky high above the Olympic Stadium. Based on a spherical basic shape, the design consisted of 120 rectangles unfolding into the Tokyo 2020 Olympic Games logo. The three different sized rectangles represented diverse cultures, countries, and ways of thinking.

This spherical base shape also represented the second section in the drone performance. The transition from the Tokyo 2020 Olympic Games logo to the spherical shape allowed the initial geometric construction of the logo visible to the audience.

The drone show was intended to underline the diversity represented in the logo, with the spherically arranged rectangles morphing into a globe in the third section of the drone show. For the globe itself, Fibonacci Sphere was chosen as the base body. In this way, we achieved an optimal and optically harmonious distribution of the drones.

The simplicity, elegance, and graceful flowing movements of the drone show presented special challenges for the show design. Usually, the customized Intel Light Show Editor calculates the transitions between two choreographed pieces of content. Here, however, these transitions had to correspond to the construction of the logo as well as a specific temporal pattern and a manual animation was simply impossible because of the large number of drones.

To meet the customer-needs during the design process, the creative team accommodated frequent requests for changes to ensure alignment to accompanying music that was still being fine-tuned. So, it quickly became apparent that a semi-procedural approach was needed to allow the artists to implement changes in the shortest possible time. With the assistance of our Intel Light Show Editor (Figure 4), it would be possible to make potential simple edits in real-time. In addition, this allowed us to test a wide variety of ideas before on-site rehearsals.

The color palette consisted of pure white with subtle traditional Japanese indigo blue accents to underline the three-dimensionality of the forms and thus the depth.

3.3 Technical Challenges of Show Design

Along with the design and creative tasks, the team had to contend with limited airspace as well as the locations and line of sight of the broadcast video cameras.

In February 2020, the team conducted a site survey of the Japan National Stadium. Since the drone operations airfield was 300 meters (about the height of the Empire State Building in New York City) away from the actual center of the drone show, it was important that the virtual models also corresponded to the exact dimensions on site. Too large a deviation in position or height would have resulted in part of the show not being fully visible. When we saw the drones appearing at the anticipated point in the sky during the first rehearsals, we had confirmation that our plans corresponded to the actual conditions on-site.

The feeling is indescribable when at the end of such a project you can finally look at your work in the night sky.

3.4 Drone Light Show Planning

To put on a drone light show using 1,824 drones in the center of an urban environment such as Tokyo, before a live broadcast with such a high-profile audience, required months of collaborative working sessions with numerous local authorities. The focus for all agencies was safety before, during, and after the flight and an unforgettably positive audience experience.

The biggest challenge facing the world was the coronavirus disease 2019 (COVID-19) pandemic which delayed the games by one year. Due to travel restrictions, the team had to develop unique solutions to obtain all the necessary approvals before the team arrived in Tokyo.

3.5 Safety and Security Consideration

Safety is a priority when operating a drone light show. It all begins with technology powered by Intel : purpose-built drones, state-of the-art animation and perform-
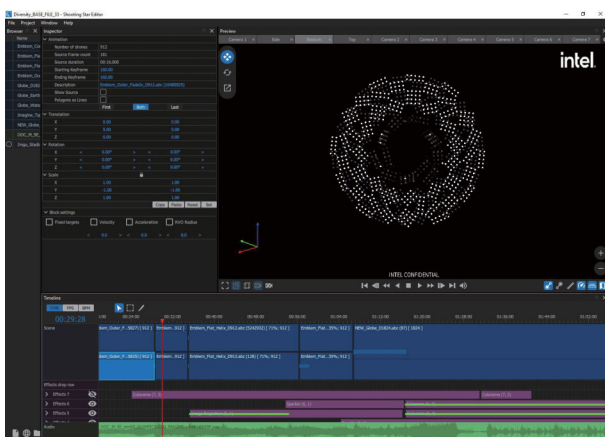

Figure 4 The Logo of the Tokyo 2020 Olympic Games in Intel Light Show Editor (©2021-Intel Corporation)

ance control software including the firmware, control software, animation, and simulation design software, to protocols intended to promote safety.

The Intel Premium drones are more aerodynamic than previous generations, meaning they can fly faster, make quicker, more agile transitions, and have an increased tolerance for wind. Purpose-built for safety, the premium drones weigh just 340 grams and are designed specifically to not carry a payload. They are also constructed with a frame made of flexible plastic and foam with guards surrounding quadcopter propellers.

During the drone development phase, the team reviewed the historical temperatures for the summer season in Japan. Based on the data, the team added to the plan how to address high ambient temperatures. To prevent the drones from overheating, special attention was focused on the thermal design of the drones. With innovative cooling solutions in the drone and launch pad systems, all systems were kept cool both on the ground and in flight.

Before any Intel drone could fly in Tokyo, Intel had to apply for radio certification to operate the drones in Japan. Once the team was on-site, an inspection and audit of the equipment and communication system was conducted by local authorities to complete the registration and certify the drones as Tokyo 2020 licensed radio devices. The audit also established frequencies used during the Opening Ceremony and confirmed that key safety protocols were working.

Next, the Intel Premium drone system security was reviewed by Tokyo 2020 Technology Service Officials for safety and intrusion protocols to check whether any outside entity could easily gain control over the drone light show system. To avoid outside interference, all communication between the drones and flight controller is encrypted. The firmware and all the flight records are also encrypted to protect the systems.

To fly nearly two-thousand drones in an urban area of Tokyo, Intel performed a live demonstration of the Intel drone system, conducted flights, and presented key safety features to the local police. The Intel animation software enables the creative team to design, test and simulate the 3D imagery. The customized software promotes safety by automatically mapping collision-free trajectories between the drones during flight and physical obstacles such as buildings. The Intel performance control software enables a single computer to manage the entire fleet. From setting geofences to running fleet checks, this robust software also allows the team to implement emergency protocols, such as return to home and immediate controlled descent. The drones are constantly reporting back to the pilot their status via the control system to keep the pilot always informed on the fleets health. The flight control system is also designed with redundancy which means if one system fails another system will keep the drone flying without any disruption.

To fly the drones within restricted airspace, the team correspondingly secured approval from Tokyo 2020 to deregulate the airspace over the Japan National Stadium for two weeks. The deregulation approval also communicated to other activations in the area to be aware of the airspace restriction during the drone light show at the Opening Ceremony. Once the deregulation was approved, Intel applied for an aviation permit from the local civil aviation authority. This was also not without challenges as the regulations for the exclusion zone and the maximum height for drone flights had a significant impact on the allowable airspace and animation design. The last step was to notify the local community, fire department, venue owners without revealing the performance.

Another concern for Tokyo 2020 was the potential noise or buzzing hum of 1,824 buzzing drones flying next to the residential area. To reduce any probable noise pollution, Intel sent the drones to a laboratory for sound level measurements during the engineering product build. Although the team specifically-built a quiet drone, the on-site testing confirmed the minimal sound produced by the drone fleet would not be detected outside of the stadium area. During the Opening Ceremony, the music aptly drowned out the soft buzzing sound during the performance.

Planning for the drone light show took place during the COVID-19 pandemic complicating an already complex process. The most significant impact was the reduced number teammates approved to enter and work the show by Japan border-control authorities. Working with half the desired number of workers, Intel built redundancy among the staff to support the daily operations. As a precaution, before the team arrived in Tokyo, the drone team divided into two groups before entering the country. The teams worked split shifts to support day and night shifts. The day shift performed maintenance and applied any updates to the fleet before the night shift conducted test flights and addressed any technical issues.
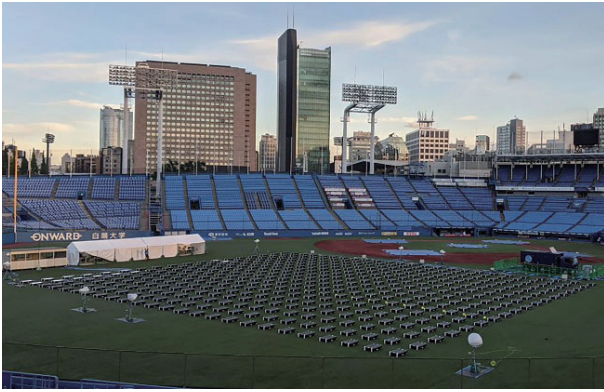
Figure 5 Meiji Jingu Stadium Baseball Field Served as the Drone Airfield （©2021-Intel Corporation）

Figure 6 The Intel Drone Light Shows Team at the Olympic Games Tokyo 2020 （©2021-Intel Corporation）

3.6 Setup, Test and Rehearsals

Intel and Tokyo 2020 explored multiple locations around the Japan National Stadium for a suitable drone airfield that would be feasible for the Opening Ceremony performance. During the site survey in February 2020, Meiji Jingu Stadium was identified to be the best site for drone airfield from an art, safety, and logistics point of view.

As part of standard operations, Intel stocks additional drones to support test flights and to secure the exact number of drones available for the final performance. Intel apportioned 2,700 drones on the airfield to support the Opening Ceremony and the animation for the Tokyo 2020 social media campaign. The Intel team worked with a local vendor to acquire the necessary infrastructure to support the daily operations of the drone team. It took 18 hours to build the airfield with all the infrastructure and set up the airfield（Figure 5）and conduct safety and power checks. The stadium would be the home of the team for the next two weeks.

Every drone flight includes a wide range of safety measures, including geofences with generous buffers, multiple trained visual observers, and built-in emergency protocols. It was no different for the Tokyo 2020 Opening Ceremony except for the movements of the participants and the parade of athletes scheduled to be in the area during the drone light show performance. To ensure the safety of people within the flight area, Intel collaborated with Tokyo 2020 authorities to develop safety protocols to confirm there would be no material breach of the exclusion zone by placing security officers around the flight area. The Intel drone operators for the Tokyo 2020 Opening Ceremony were highly trained and licensed pilots with years of aviation experience expertly trained and skilled in risk management, worldwide aviation regulations, weather, and airspace awareness.

Another challenge the team had to overcome was the radio frequency interference experienced by the system in the stadium area in the middle of Tokyo during test flights. Because the Opening Ceremony is such a large production, nearly every vendor was using radio communication as part of their setup, causing interference with the drone communications. With redundancy optimized radio protocol in the drones and careful radio transmitter box locations, the team managed the electromatic frequency interference and executed a successful drone light show for the Opening Ceremony.

The final and the most critical challenge was synchronizing the drone light show to the live performance of the elements of the story choreography inside the Japan National Stadium. For the live performance, it was critical that the drone flight trajectories, lighting, and music choreography matched precisely to engage the audience and to send a message of unity and hope to all the viewers across the world.

4. Opening Ceremony

The team arrived early as there was an area lockdown due to security and safety protocols for anyone entering the restricted area on the day of the Opening Ceremony. As you might expect, on show days, the team often has a higher level of stress and anxiety as they focus on flying a best-in-class show, but with millions of people watching worldwide, the stress levels skyrocketed.

As the sunset on the night of July 23, 2021, the pilots and professional show controllers ran through the final safety and equipment checks and then launched the

show. The Intel drone performance has been widely celebrated as one of the highlights of the ceremony. From glowing newspaper and magazine reviews to extensive television broadcast coverage and social media engagement, this magical performance has become one of the most talked about events of the Tokyo 2020 Olympic Games.

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Tapio LIUSVAARA received his M. Sc. in Mechanical Engineering from Tampere University in 1998. He is a Principal Engineer at Intel Corporation. Tapio has R&D experience in mobile phones, tablets, wearables, and light show drones.

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Andreas JALSOVEC
Andreas JALSOVEC studied graphic design in Linz, Austria. Attracted by the possibilities of computer graphics, he deepened his knowledge in digital modelling, 3D animation and visual effects. Based on these skills, he became a key researcher in this area of the Ars Electronica Futurelab shortly after its founding in 1996. As early as 2012, as part of the Ars Electronica Spaxels project, he had the privilege of realizing the world's first drone light show. Artistically exploring the possibilities of drone light shows and pushing the boundaries of their application is his current focus at Intel.

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NAGASE Jun received his diploma in Law from Meiji Gakuin University in 1995. Prior to joining at Intel in 2005, Jun established his Sales career in the semiconductor industry. He has participated to Olympic Program Office at Intel in 2018 to support projects in relation to Tokyo 2020.

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