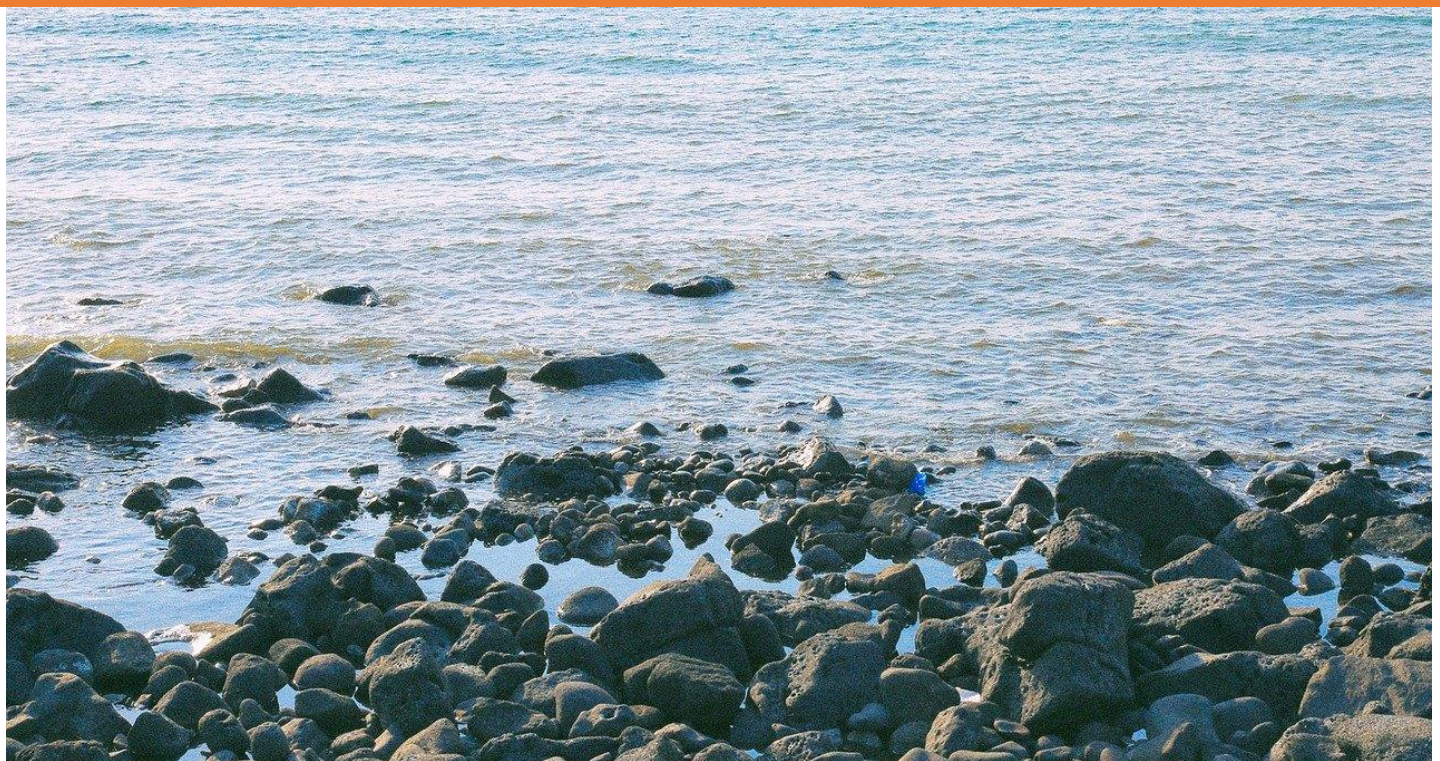
Doosan Mobility Innovation CASE STUDY

"Hydrogen fuel cell drone, an efficient solution for mask delivery in Jeju Islands"



Case Study

Application	Industry	Region
Delivery	Healthcare	Korea

Overview

At an era when facial masks are becoming the essential part of our lives, hydrogen fuel-cell drone fly to the rescue with its delivery. On April 16th, Doosan Mobility Innovation(DMI) delivered 15,000 masks to 3 local islands in Jeju: Gapa Island, Mara Island and Biyang Island. It was the first BVLOS flight conducted inside Jeju Island, attained through special waiver of Korea's Ministry of Land, Infrastructure and Transport(MOLIT). The masks are enough for 3 months' use by the islands' 490 residents, based on 2 usage per week. As the infrastructure such as pharmacy or post office is unavailable in remote islands, drone delivery will prove to be an innovative solution in Covid-19 period.

The Challenge

Located off the coast of Jeju, the 3 islands (Gapa, Mara, and Biyang) are one of the remotest area in Korea, and basic necessities are hard to get. A problem even among normal times, this inaccessibility is emerging as a serious issue in Covid-19, when every citizens are in desperate need of facial masks. Ferries come by only 3-4 times a day, a round trip impossible after 2 p.m., and composed mostly of tourists, are unsuitable for logistics. As a result, to get the supply needed, residents have to wait for a day at minimum.

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DMI's experienced team is ready to help increase productivity in customer sites with long-endurance drones

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"As there are no pharmacy or post office in Gapa Island, there were concerns about public mask supply. Now I can be rest assured with drone delivery."
- Won Heeryong, governor of Jeju Providence

The Solution

1 BVLOS flight based on hydrogen's long endurance and LTE monitoring range

DMI hydrogen fuel cell drone successfully completed its first BVLOS flight in Korea, despite heavy winds and the lack of base transceiver station at sea. As the flight control was based on LTE communication, there are no distance limitation for flight. In the event, DMI was able to remotely monitor and control its drone apart 9km distance, and the drone automatically took off and flew back to its home base after landing. Even when the LTE connection was momentarily lost, DMI's Ground Control System ensured the drone to continue its automatic mission flight. DMI View, a digital platform developed by DMI that encompasses GCS and monitoring Dashboard, provided real-time data of hydrogen fuel cell powerpack and the drone during the flight.

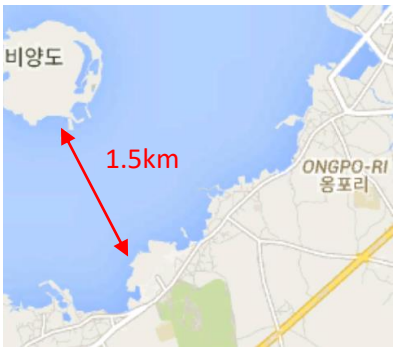
DMI drone during BLVOS flight to Gapa Island

2 Wind Resistance for Over-Sea Flight

With the enhanced model equipped with high wind resistance features, DMI drone, DS30, maintained reliable flight in wind speed 10m/s. Although such strong wind prevented the drone from flying to its full speed that more than doubles employed 5m/s, there was no single stop or hovering during the mission, demonstrating the ease DS30 could pull off in harsh environment. Doosan Mobility Innovation is further developing its model to reinforce its wind resistance at stronger wind, and with higher speed.

Benefits

Doosan Mobility Innovation
Safe and efficient solution for Mask Delivery



At the event, DMI completed its 4 round trips to and from 3 islands—2 round trips to and from Gapa Island, 1 from Mara, and 1 from Biyang Island. The whole flight took about an hour and a half, and was conducted using 1 hydrogen tank, without additional refueling. Considering the immense energy and economical cost of ferry or helicopters, drone delivery is remarkably efficient. At DMI's earlier demonstration at US Virgin Island with Skyfire Consulting and USDOH, DMI drone travelled 70km in just 2 hours of time.

Moreover, using drone enables contactless delivery that can reduce the possibility of infection, a significant detail in the wake of Covid-19. Without a pilot or a captain undergoing the actual delivery, human interaction can be minimized. This means the decrease of labor cost but also means the safety of workers. This long endurance hydrogen fuel-cell drone can make long distance, unmanned delivery a reality.

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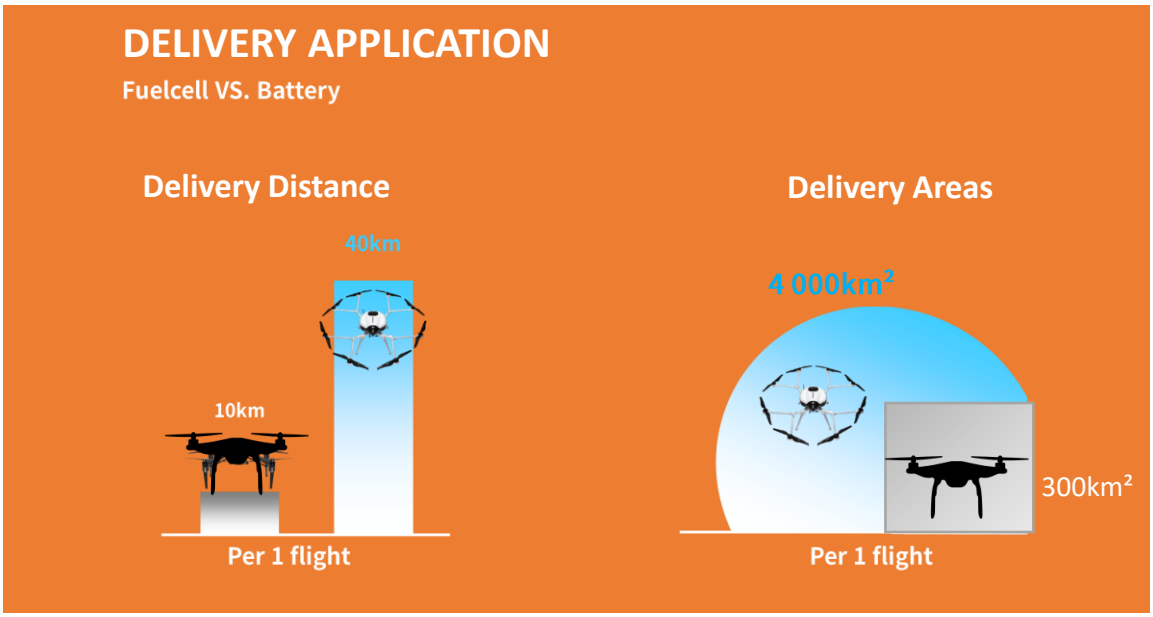
[CASE STUDY] "Hydrogen fuel cell drone, a radical solution for aid delivery in US Virgin Islands"



Since the outbreak of Covid-19, the number of drone applications has doubled, as employee safety became the serious issue to consider at worksite. Doosan Mobility Innovation offers a unique solution with its hydrogen long endurance fuel cell drone that utilizes the high energy density of hydrogen fuel cell. Maximizing the 2 hours of flight time unparalleled with conventional battery drones, DMI drone can fly to and back 40km of distance, 80km if one-way. In terms of delivery areas, this implies more than 13 times of spaces a drone can cover.

With the software ready for effortless Beyond Visual Lines of Sight flight, and strong hardware that can withstand heavy wind, DMI hydrogen drone can set a new path for delivery.

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Doosan Mobility Innovation CASE STUDY

"Hydrogen fuel cell drone, a radical solution for aid delivery in US Virgin Islands"

Case Study

Application	industry	Region
Delivery	Healthcare	US Virgin Islands

Overview

Hydrogen fuel-cell drone can be best described as “drone ambulance”, as it enables aid delivery in United States Virgin Islands, where the infrastructure is frequently devastated by massive hurricanes.
With two-hour flight, Doosan Mobility Innovation(DMI) is able to make 45 miles of flight[1], procuring medication to those in dire need. In November 8th, 2019, DMI successfully completed a 43 mile flight between St. Croix and St. Thomas, carrying 40 simulation vials and health supplies, with 30 minutes of hydrogen remaining. The event was also planned and carried out by Skyfire Consulting, U.S. Department of Health (USDOH), and Association of Public Health Laboratories.

The Challenge

The United States Virgin Islands (USVI)—made up of St. Croix, St. Thomas, and St. John—is notably vulnerable to hurricanes, as it severely impacts the islands every three years on average. During the Atlantic hurricane season that reigns from June to November, the islands suffer from the lack of crucial supplies including medical equipment. Ports and airports are mostly closed for protection, and according to the personnel

1) DMI drones can fly up to 2 hours, with 10m/s speed at most (22.5 miles/hour)

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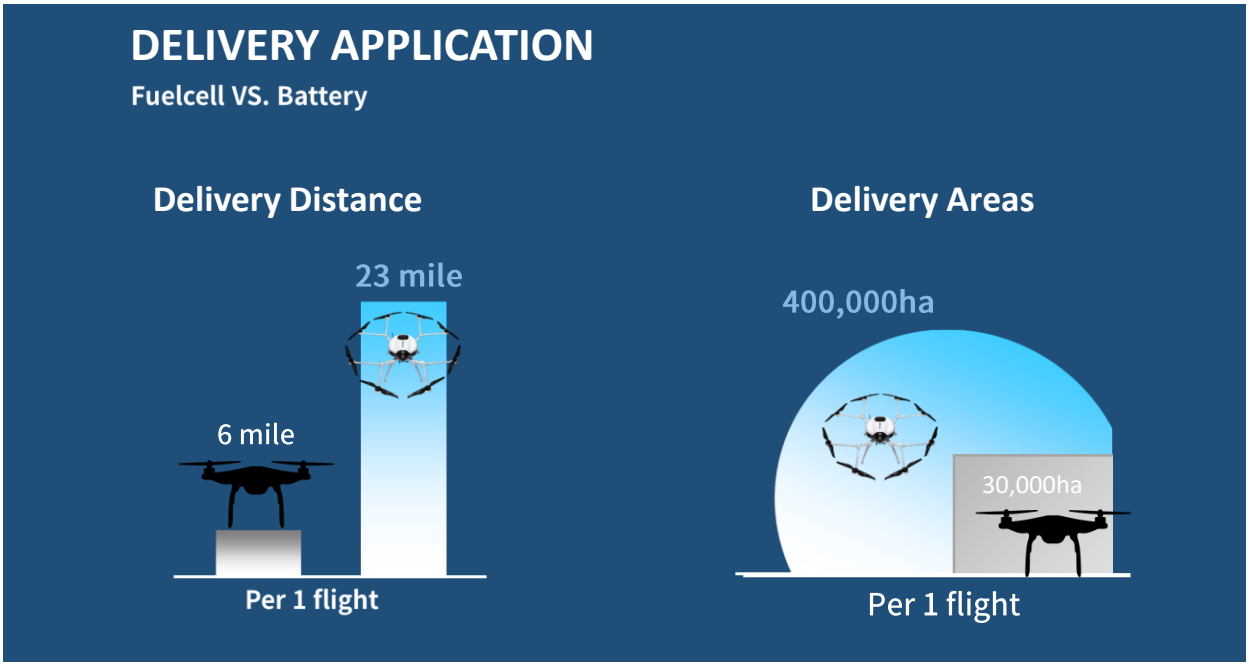
from Department of Health, boats or seaplanes that are currently employed are "not the most efficient or reliable transport following a disaster". Two main problems, one of the cost, and the other of rescue team's safety, remain. Still, in order to timely assist those in need and prevent the disease from rampaging the islands, deliveries must be made in any form.

"··· the Department of Health had to rely on any means possible to transport critical health-related materials. ··· Often times, responders were forced to batch samples and wait."
- Brett Ellis, public health laboratory director for the USVI Department of Health"

The Solution

1 Drones that can fly long distance

Drones that can mitigate human casualties are perfect for delivery in dangerous areas. This might not be the case in Virgin Islands, as US Virgin Islands are 40-50 miles east of Puerto Rico, far exceeding the traditional battery drone's capacity. As battery drones have limitation in terms of flight time, only 12-13 miles of travel is possible in a flight. In contrast, as proven in the demo event, DMI have drones that can fly more than 40 miles, covering the distance at ease. This is made possible due to hydrogen fuel cell's high power density, which is 3-4 times of that in battery drones.



Delivery distance and areas, based on round trip

2 Real-time Software System for Safe and Reliable Flight

Along with the hardware, DMI provides customers with the software solution, Ground Control System (GCS), that allows users to intuitively plan flight missions. Because GCS is a web-based system, it can utilize crucial information including weather in real-time, enhancing user experience. Through another key software, DMI Dashboard, end-users can check detailed information of the drone in play including power consumption and remaining hydrogen. This is especially important in the sea areas, where turbulent environment calls for immediate response.

DMI's GCS (left) and Dashboard (right)

3 Payload Specialized for Temperature & Movement Control

In the event, DMI cooperated with RDG Company, renowned for manufacturing customized storage cases. Since simulation vials and vaccines are highly susceptible to temperature and movement, using specialized case was an appropriate measure to ensure safe delivery. This was additionally possible due to DMI drone's ability to carry up to 5kg payload, and its vertical take-offs and landings, which reduces the impact of flight to the package.

- a special case designed specifically to be carried by drones by RDG Company.
- Qualified for chilled and ambient temperature
- Able to control shakes and vibrations, suitable for handling sensitive materials

DMI's Hydrogen Fuel Cell Drone with RDG case attached

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Benefits

Doosan Mobility Innovation,
Safe and efficient solution for USVI

> *"The purpose of doing all of this was to enable the USVI Department of Health to provide more efficient services, test results and vaccines to the citizens of these islands. This win is a very important first step towards that goal.*
> *- Matt Sloane, CEO and co-founder of Skyfire"*

DMI's hydrogen fuel cell drone is the safest and the most efficient solution that enables timely yet affordable delivery with no human damage.

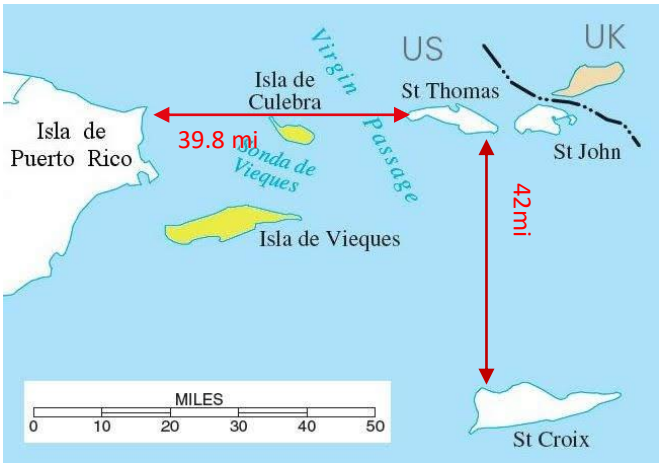
Safety

Drones that enable unmanned operation are secure beyond comparison to seaplanes or boats. During the hurricane season, most ports are out of service, and pilots in the mission brace themselves for the worst. The idea of staying in the isolated island with more hurricanes in prospect is threatening as well.

As Beyond Visual Line of Sight (BLVOS) flight is authorized and implemented throughout United States, drone deliveries can rule loss of life out of possibility.

Among drones, DMI drone is the only UAV that proved the precarious 43 miles overseas flight. With reference to the map below, DMI drone can cover distance between Puerto Rico and St. Thomas as well as St. Thomas and St. Croix.

With autonomous mission flight and emergency flight settings, DMI drone can keep not only casualties but also harm to packages and machine to the minimum. Whenever there are issues regarding the condition of drone, fuel, or network, the software is designed to return to home or hover.



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Cost

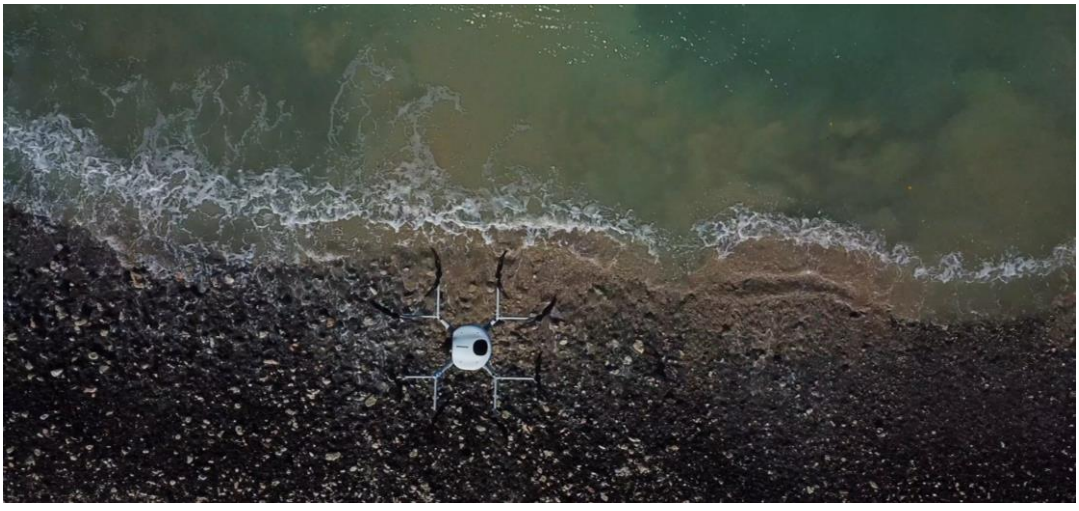
DMI drone is the most efficient solution for aid delivery, as it is cost effective in terms of money and time, beyond comparison to conventional jets or boats.

Airplanes are more often than not invalid for use during the hurricanes, but in rare use cases, prove to be hugely expensive. For instance, chartering a private jet in a rescue mission cost $112,000[2] in 2017.

More inexpensive boats require weeks to be prepared, and are slower than flights.

Hydrogen fuel-cell drones can resume another mission with simple replacement of tanks that takes less than 5 minutes. Therefore, almost relentless delivery to and from the island is possible, with 6 round trips possible in 24 hours, given approximate 2 hours of flight time to reach the island. In a situation where punctuality is the key, this fact holds profound meanings.

With this reliable, affordable, quick and green solution, United States Virgin Islands will be able to keep disaster at bay, saving lives and reducing illness drastically.



2) On September, 2017, Virginia Beach's Island Dog Rescue chartered a private jet for animal evacuation during Hurricane Irma

Doosan Mobility Innovation CASE STUDY

"Hydrogen fuel cell drone, an innovative solution for search and rescue in Virginia Beach"

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Case Study

Application	Industry	Region
Search & Rescue	Public Safety	Virginia Beach

Overview

Drone has always been one of the new technologies that can be used in public safety. With the potential to do lots of things from gathering data about a fire, to finding lost person ahead of officers, drones can put people out of harm's way.

Doosan Mobility Innovation (DMI) has joined 14th Steven Todd Dooley Search & Rescue (SAR) Forum 2020, led by the Virginia Port Authority and United State Coast Guard (USCG) Sector Hampton Roads.

DMI cooperated with one of the biggest carriers in US, Verizon, broadcasting in real time to its first responder team. By two-hour flying drone, DMI sent high-definition videos and thermal imageries to detect casualties or survivors in the sea at nighttime.

The Challenge

Drones are flying to the rescue in the emergency response sector, assisting search and rescue teams in identifying victims lost in the wilderness. Not only does drone gather footage and data from the scene, it helps first responders cut down the expenses, keeps them safe and speeds up the sector.

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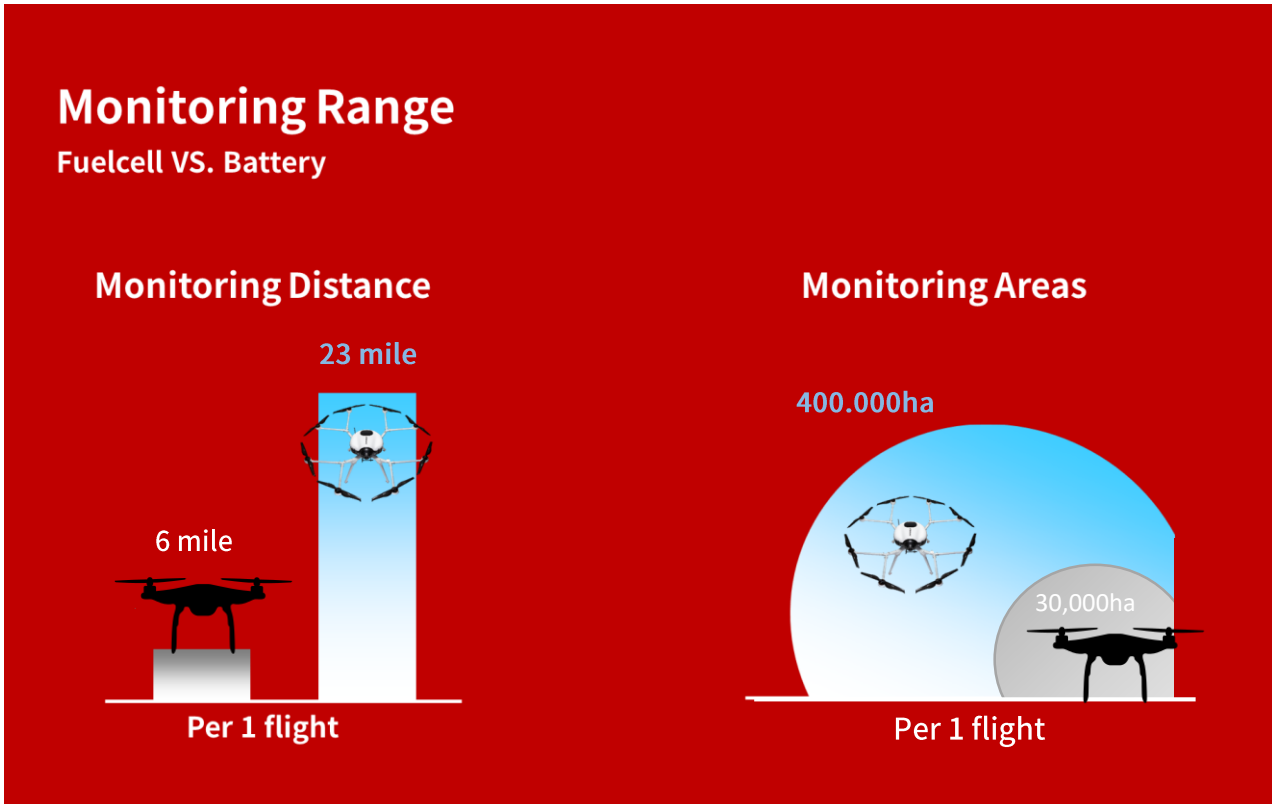
However, the environmental condition does not always help crews use drone as they want. When the disaster strikes or when there are lost people in the sea at night or in a very foggy weather, drones with 15 to 30 minutes of flight time might not help. Longer, more stable use of visibility equipment is required.

The Solution

1 Longer flight time, longer monitoring

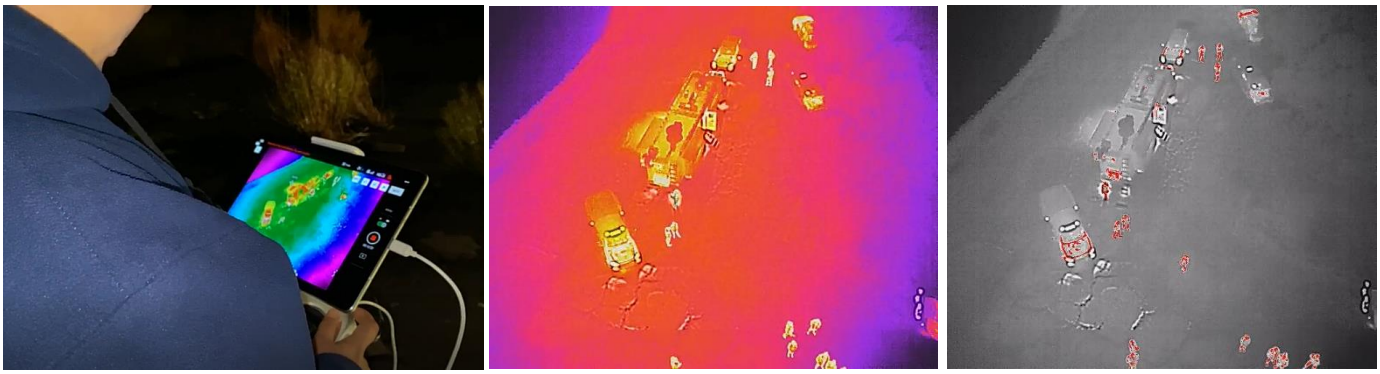
Being able to understand what is going on in the middle of the disaster such as typhoon in the sea is critical to first responders. Using drone to identify and monitor the situation is becoming common in search and rescue operations.
However, the limitation of flight time in conventional drones makes it very difficult for people to support these operations.
For this reason, in this event, two-hour flying drone of DMI with EO/IR dual camera was used to monitor the situation and detect people in the sea at foggy night. The drone broadcasted the video by LTE communication to Verizon’s first responder team, defining where they should go.



Flight distance and areas, based on round trip

2 Sensors for Identifying & Detecting current situation and Survivors

To identify and detect casualties or survivors, and to monitor current situation for the command center or rescue teams so that they can react in efficiency, DMI has managed to couple EO/IR dual sensor with the drone, taking both high-quality visual and thermal imageries.
By using Verizon's’ LTE communication technology, and by connecting it to DMI’s ground control system, the camera views were broadcasted to command center and rescue crews on site, enabling the delivery of right supplements to the right location.



IR Camera View

3 Real-time Software System for Safe and Reliable Flight

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DMI View GCS and DMI View Dashboard

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Benefits

Doosan Mobility Innovation,
An innovative Solution for Search & Rescue

“The limitation of conventionally powered UAS makes it very difficult to maintain persistent aerial surveillance. Batteries discharge too quickly resulting in having to return to base, switch power supplies and relaunch. This hydrogen fuel cell powered UAS changed our response abilities significantly, nearly tripling our on-station loiter time.”
- Jeffrey Schweitzer, Asymmetric Solutions Architect @ Verizon

DMI’s hydrogen fuel-cell drone can stay in the air for a longer time to monitor the situation and detect people who needs to be rescued before first responders reach the place. This allows the crew to reduce the time of locating the exact spot where they need to be, also reducing the cost of preparing medical supplement that has to be delivered.
With real-time broadcast for 2-hours of the disaster scene, command center can always react quickly on various circumstances, relying on the inspection equipment.

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Doosan Mobility Innovation CASE STUDY

"Hydrogen fuel cell drone, an innovative solution for emergency delivery in Africa"

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Case Study

Application	industry	Region
Delivery	Healthcare	Rwanda

Overview

Hydrogen fuel-cell drone can be utilized as a “drone ambulance” by transporting medical supplies in Africa where the infrastructure for roads and traffic is not well established.
With two-hour flight, Doosan Mobility Innovation(DMI) is expected to be able to make 40 kilometers of round trip per flight, and to save 5,000 lives with one drone a year. DMI attended the Africa Drone Forum(ADF), organized by the World Bank to confirm the possibility of building an innovative African logistics infrastructure through hydrogen fuel-cell drones, and successfully completed a demonstration of emergency supplies delivery in front of 70 potential customers.

The Challenge

According to the WTO, 5.6 million units of blood were collected in Africa in 2018 to solve the issue of high mortality rate in Africa[1]. However, the shelf life of blood is up to 42 days when stored in refrigerators at 6ºC, but only 5 days when stored at room temperature. Therefore, donated blood is valuable only when it is delivered quickly to the person in needs.

1) WHO Global Status Report on Blood Safety and Availability

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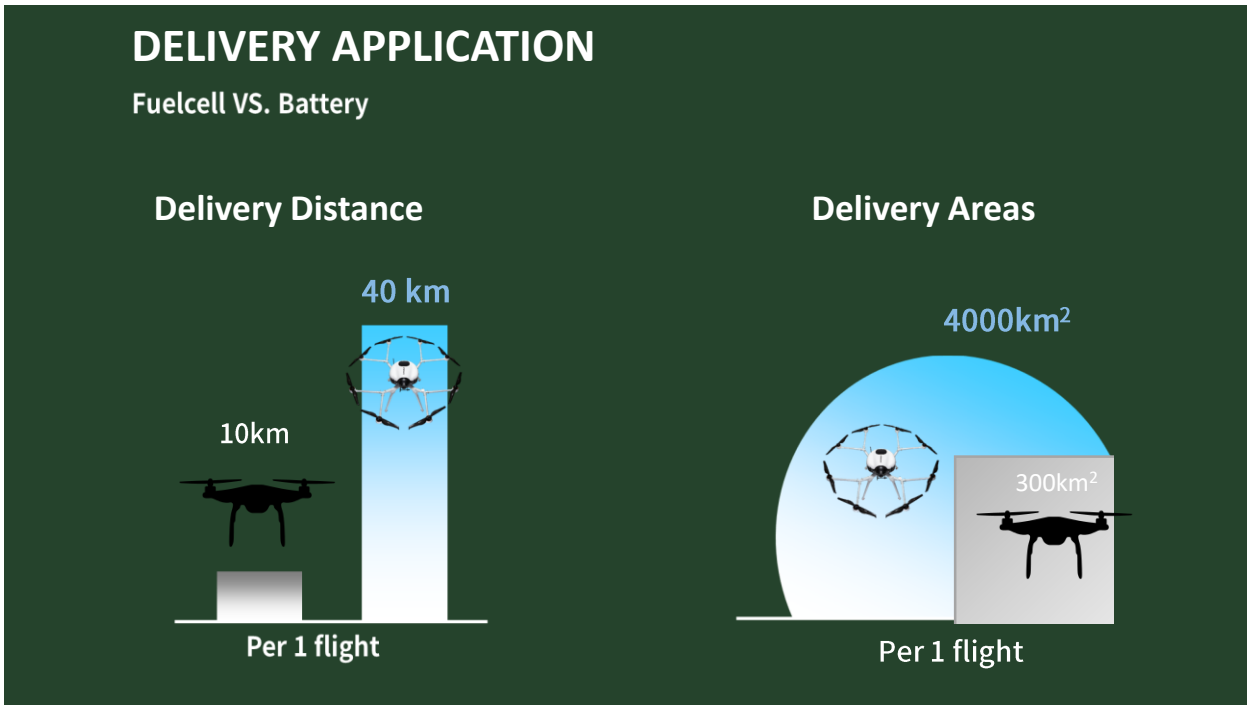
Currently, however, only 34 percent of Africa's population resides within 2 kilometers of paved roads, making it difficult to supply blood in a timely manner due to the poor conditions of existing transportation.

"As the road condition is poor, we walk at least an hour to buy the goods. We even walk much longer for medicine
- Donata Kiiza, Kibuye residents"

The Solution

1 Longer flight time, longer distance

In Africa, drones are increasingly being used to overcome the limitations of existing infrastructure and to deliver emergency supplies. However, battery drones have limits in the flight time, so only 10km travel is possible considering the time needed for returning to the starting point after delivery. Doosan Mobility Innovation(DMI)'s hydrogen fuel-cell drones can fly up to two hours, overcoming the limits of battery drones and travelling up to 40km round-trip. The distance is enough to make two round trips from Gitesi to Bugarura Island



2 Higher payload, higher productivity and keeping blood in the optimal condition

Fixed-wing drones, which are mainly used for blood delivery in Africa, generally have a payload of about 2 kg. DMI’s hydrogen fuel-cell drones, on the other hand, have a maximum payload of 5 kg, making it possible to deliver twice as much blood as battery drones per flight. At the same time, DMI drone, with 5kg payload, can carry blood in the delivery box specifically designed for temperature-sensitive medical supplies. The box itself reaches 2.2 kg, which means other battery drones cannot transport blood at all if a box is added.

DMI's Hydrogen Fuel Cell Drone with Softbox

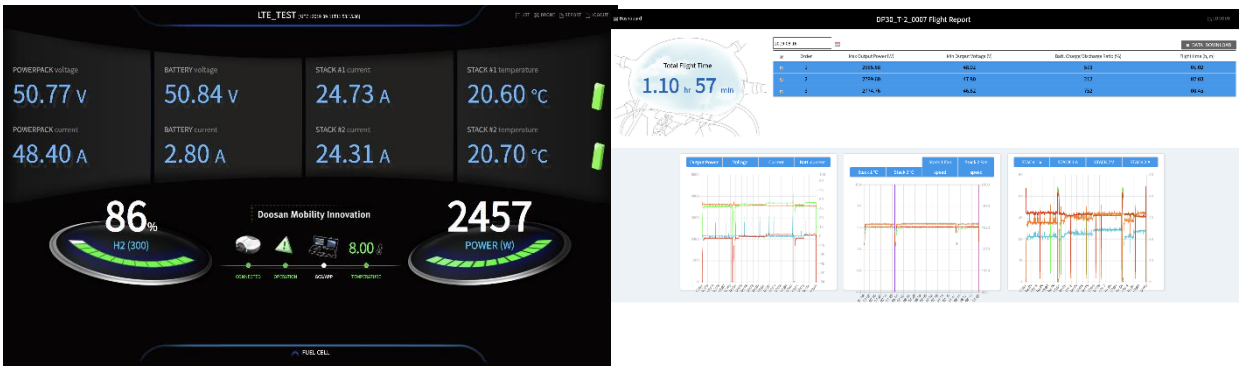
Softbox

- a special, thermally-insulated packaging system designed specifically to be carried by drones
- Qualified for chilled and ambient temperature

3 Safe and reliable flight with DMI’s multicopter

DMI drones provide autonomous mission flight specially designed for long endurance flight. In this case, safety should be prioritized since it is not possible for a pilot to manually steer the drone. DMI has a system that allows users to monitor the drone's status in real time and a redundancy to prevent issues.

End-users can check detailed information of the drone in real time including power consumption and remaining amount of hydrogen fuel, and etc. It is also designed to return to home or hover over when there are issues such as the lack of hydrogen or the loss of communication. Finally, DMI drones as multi-copters enable vertical take-off and landing, allowing them to land with very high accuracy even in tight spaces after completing autonomous missions.



DMI's real-time monitoring system

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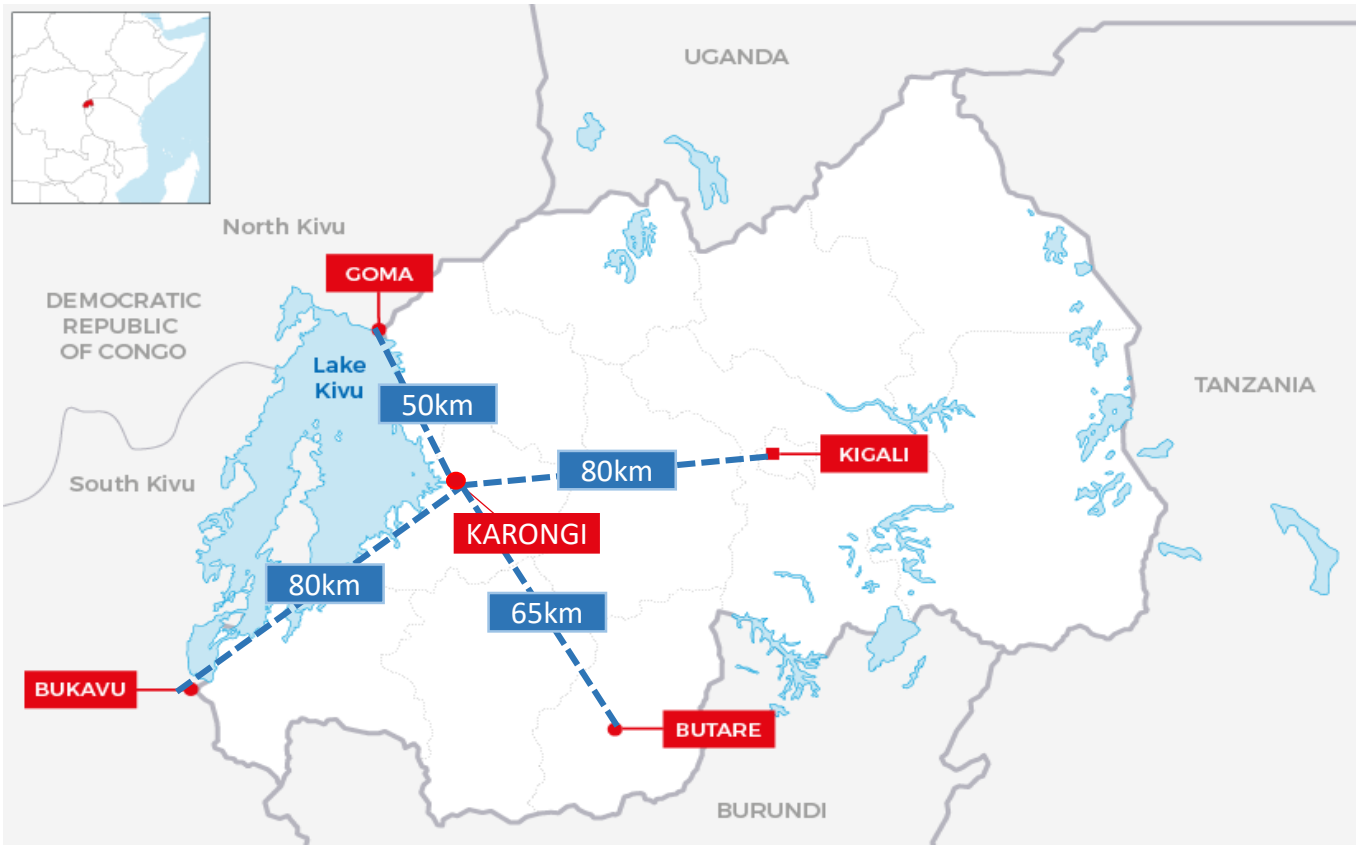
Benefits

Doosan Mobility Innovation, Clean long delivery solution for Africa

Doosan Mobility Innovation’s product is the only drone fueled with hydrogen fuel-cell. This is green technology and it stays in the air for longer time, enabling it to reach longer distance and get more economic values
- George Mulamula, Worldbank

DMI’s hydrogen fuel-cell drone can travel more distance with more safety and reliability, even carrying more medical supplies, resulting in more economical and environmentally friendly delivery. DMI drone is the most economical solution among drones to cover large areas, such as the African continent, because it can travel 80km one-way or 40km round-trip. If you apply this advantage to Rwanda, you can see that most major cities can be covered by one drone based on Karongi.



DMI drone’s expected flight map based on Karongi

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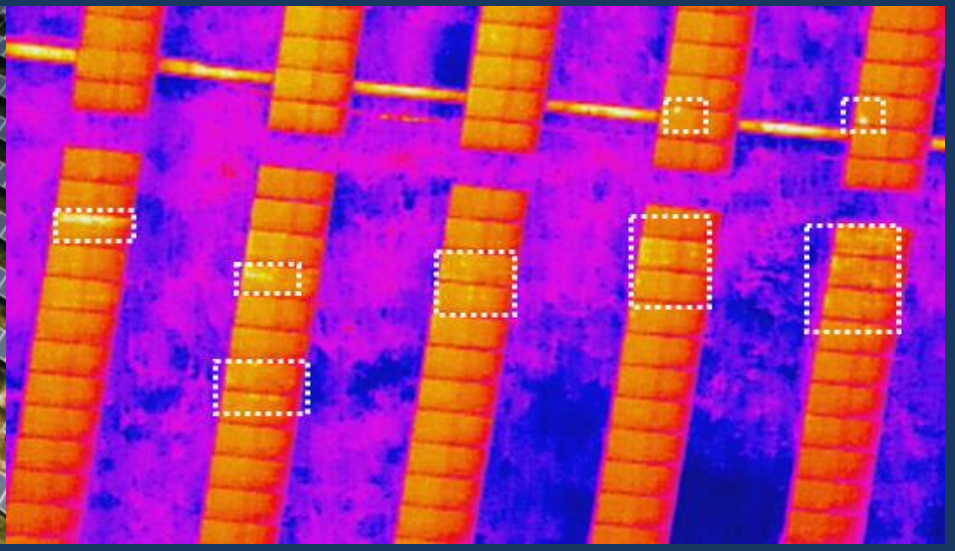
Unlike battery drones that require more than an hour of charging time, hydrogen fuel-cell drones can resume another mission with less than 5 minutes after simple replacement of hydrogen tanks. Therefore the utilization rate of fuel-cell drone can be optimized.

Finally, hydrogen fuel cell drones use green energy generating almost zero emissions. The principle of fuel-cell system is to utilize the chemical reaction between hydrogen and oxygen in the air. When hydrogen from the tank meets oxygen in the air, it generates electricity and pure moisture. Hydrogen is an abundant, inexpensive, and safe, above all, environmentally friendly natural element. Also, this hydrogen technology can provide an opportunity to activate undeveloped African renewable energy, expecting a relief from energy dependency on countries outside Africa.

DMI’s drones at Africa Drone Forum (ADF) and demo flight

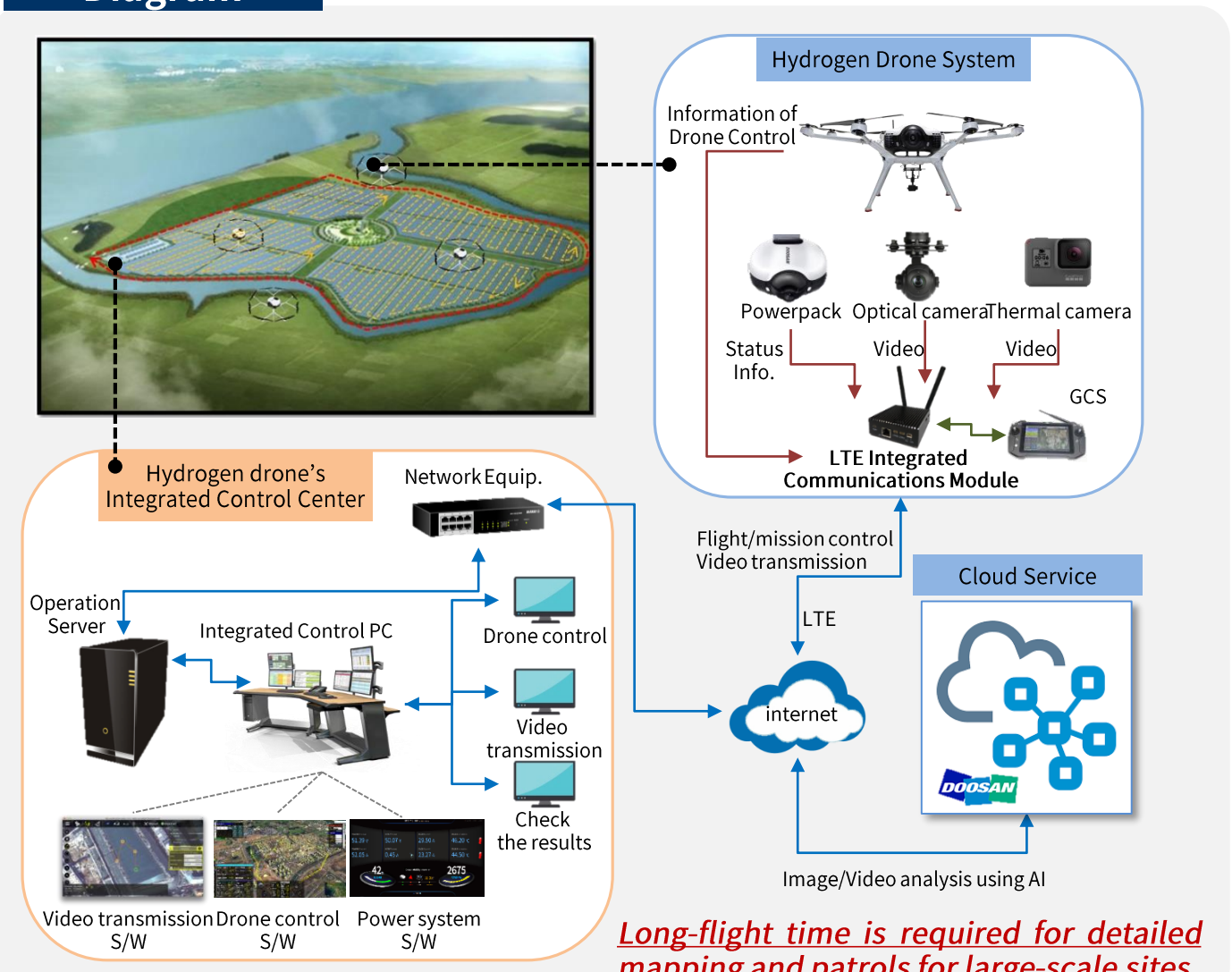
Doosan Mobility Innovation,
The Best Innovation Winner of CES 2020

Solar Plants Inspection Solution



Overview of DMI's Hydrogen Drone Solution for Solar Plants

Diagram



Long-flight time is required for detailed mapping and patrols for large-scale sites

Application/Usage

① Automatic inspection of solar module

- Automatic detection of malfunctioning modules
- Automatic grid flight
- Acquisition and transmission of thermal images & Transmission of analysis to the control center

② Patrol of plants site

- Automatic detection of abnormal environments such as fence damage
- Automated mission flight
- Real-time transmission of optical/ thermal images day and night
- Switchable to manual mode

③ Detection of changes in array shape

- Automatic detection of changes in shape
- Automated mission flight
- Cloud-based 3D mapping
- Real-time transmission of detailed optical image

DMI's Value Proposition for Solar Plants

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Specification

Type	Octocopter	**Operating distance**	Unlimited (LTE)
Size	2,600 x 2,600 x 796mm	**Wind resistance**	8m/s
Power System	Hydrogen Fuel-Cell	**Max payload**	4.5kg
Gross weight	20.4kg	**Max flight time**	120min
Maximum take-off weight	24.9kg	**Operating Temperature**	0~35℃

"Maximize Energy Production with the most Efficient, Clean, and Reliable Solution"

Efficient

Specialized in large-scale plants based on long-flight time, resulting in 6 to 8 times more efficient than battery drones

Clean

Achieve the ultimate zero emissions by using green hydrogen, which is the most suitable technology for renewable energy sites

Reliable

Control and monitor drones in real-time from the control tower by using LTE communication and automatically land in a safe place in emergency situation

Feasibility Analysis of Solar Plants Solution

Market Trend

Market

- The global solar energy market was valued at $52.5 billion in 2018 and is projected to reach $223.3 billion by 2026[1]
- **The need for long-flight drone is increasing due to the increased large-scale and low-accessible plants**

Custo-mer

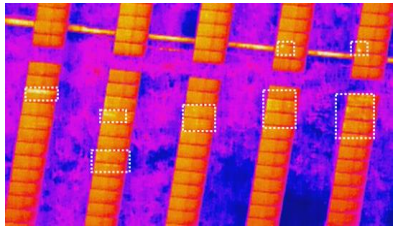
- O&M is the key for the profitability for solar plants by maximizing production efficiency and mitigating potential risks
- The need for drone in O&M is increasing especially for large-scale plants, since it can save significantly on both time and cost compared to manpower
  - ***However, battery drones have limitations in monitoring large areas because of 30 mins of flight time***

Technical and Financial Feasibility

Tech.

- Completed various flight tests and accumulated data from many different types of solar plants from 2019
- Confirmed the optimal mapping setting, such as overlap ratio and height, and verified the technical feasibility
  - **Possible to classify solar panels and detect defective panels with the 95~99% accuracy**

▲Classified solar panels



▲Detected defective panels

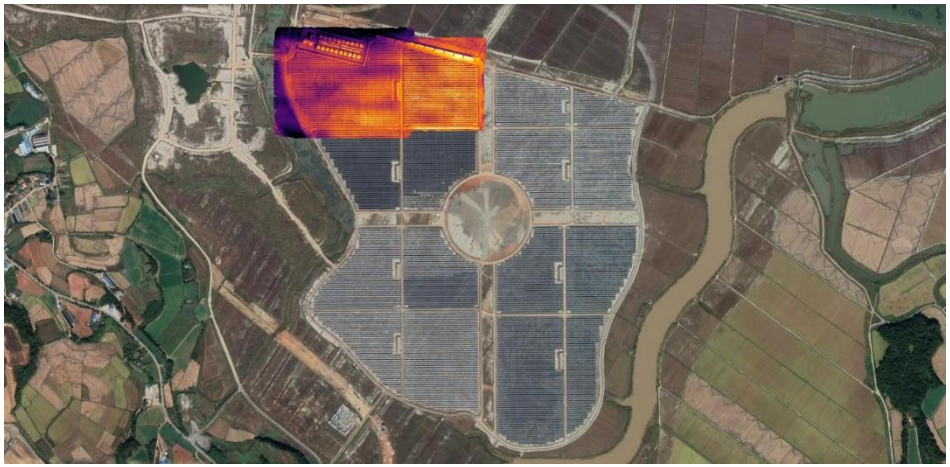
Finan-cial

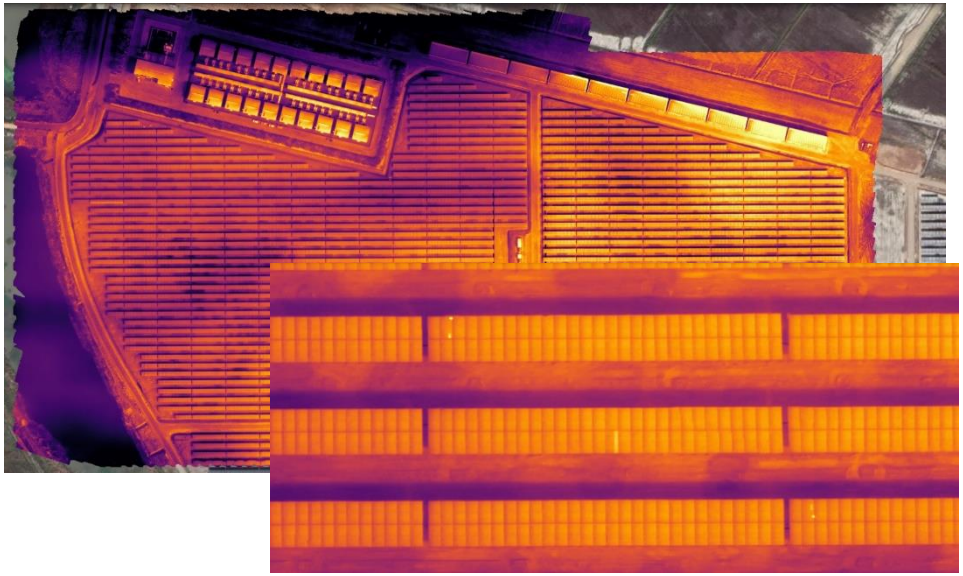
- The cost for O&M consists of labor, analysis cost, insurance, accounting mgmt., and etc., and the average is 400K $/year based on 100MW plant
- The annual cost for DMI solution is 40K $/year[2] considering the product life span and inspection cycle,
  - **Possible to identify a significant level of cost savings compared to conventional O&M method**

1. Allied market research, Global Solar Energy Market Opportunities and Forecasts
2. Based on the assumption of quarterly inspection with one hydrogen drone solution

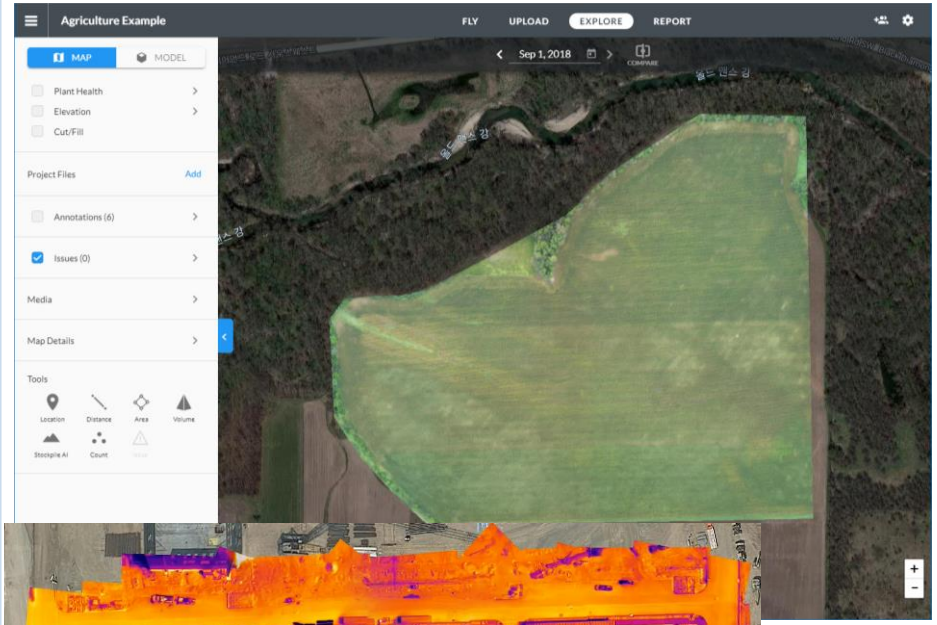
References

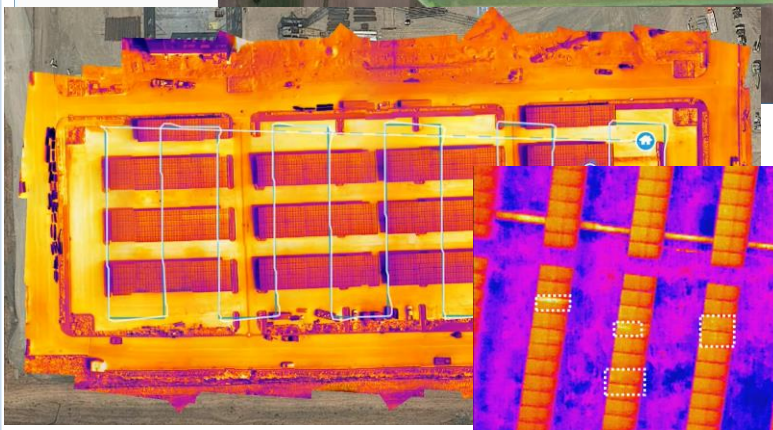
98MW Solar Plants in Korea

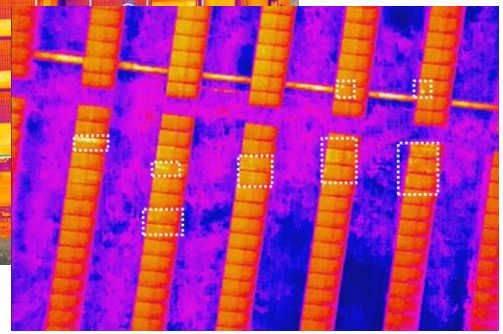




10MW Solar Plants in Korea

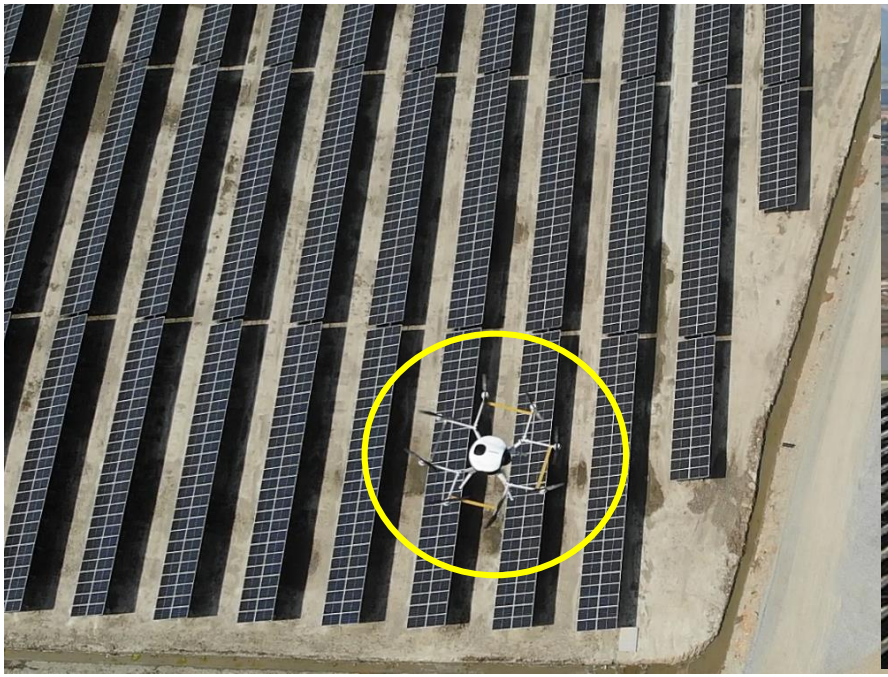


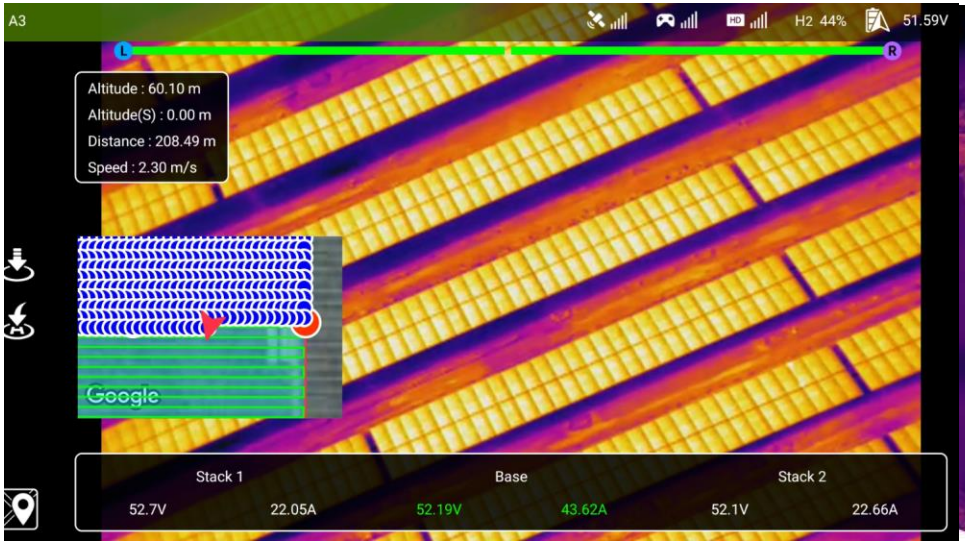




Korea Solar Plants Mapping (98MW)

Back-up





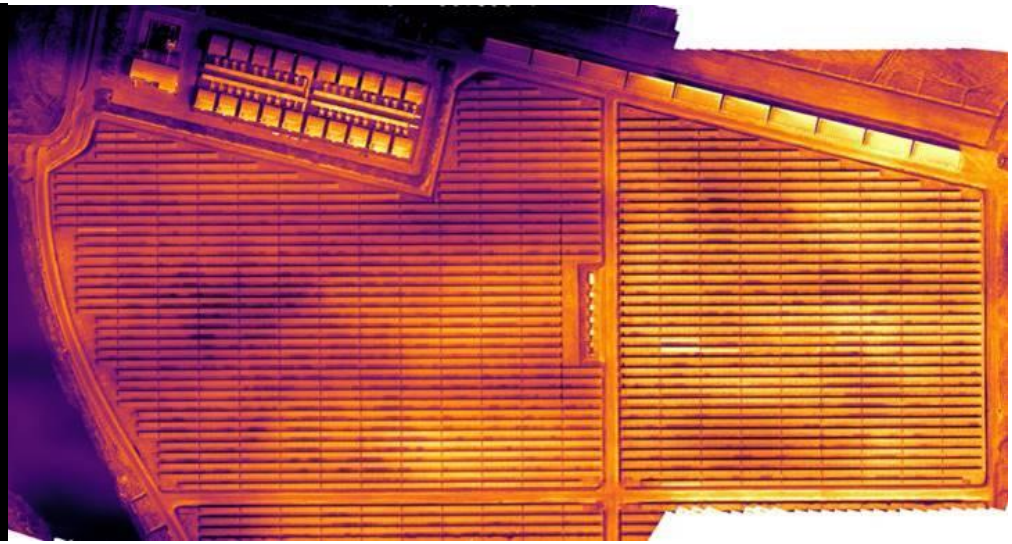


Image Analysis – 50m Above Mapping

Back-up

Detected images after Machine Learning

Original Image	Detected Image	Original Image	Detected Image

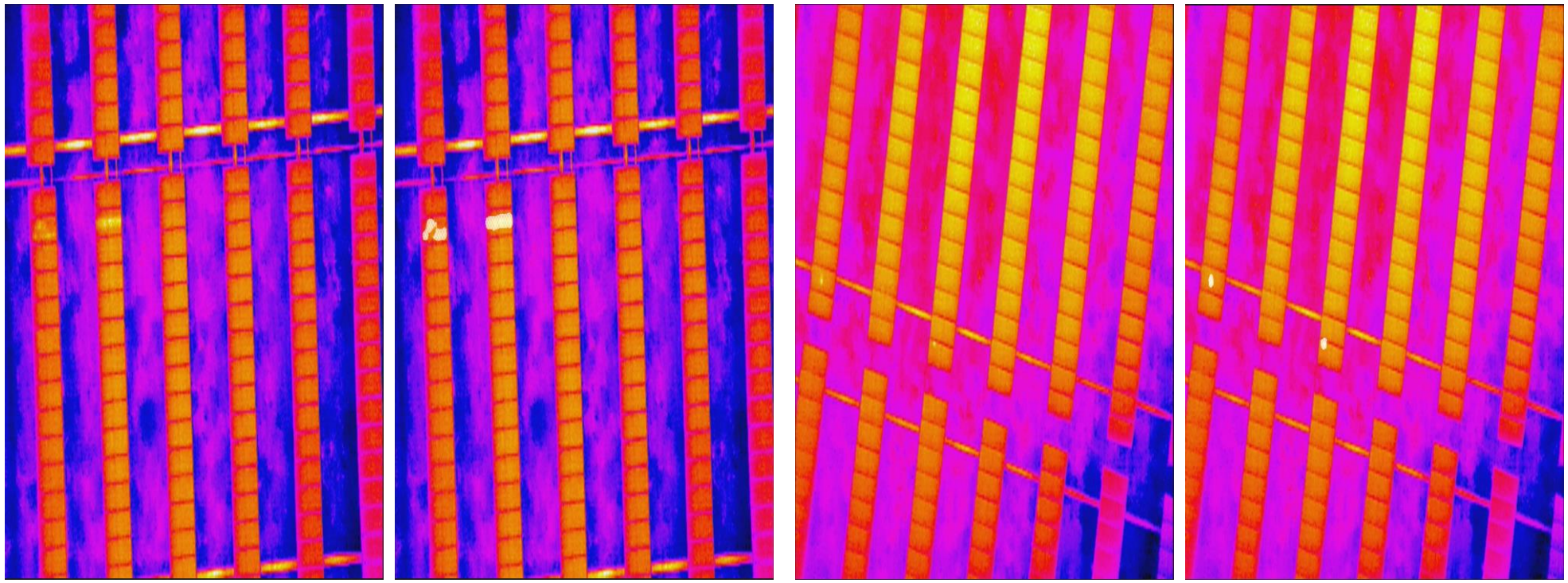


Image Analysis – 50m Above Mapping

Detected images after Machine Learning

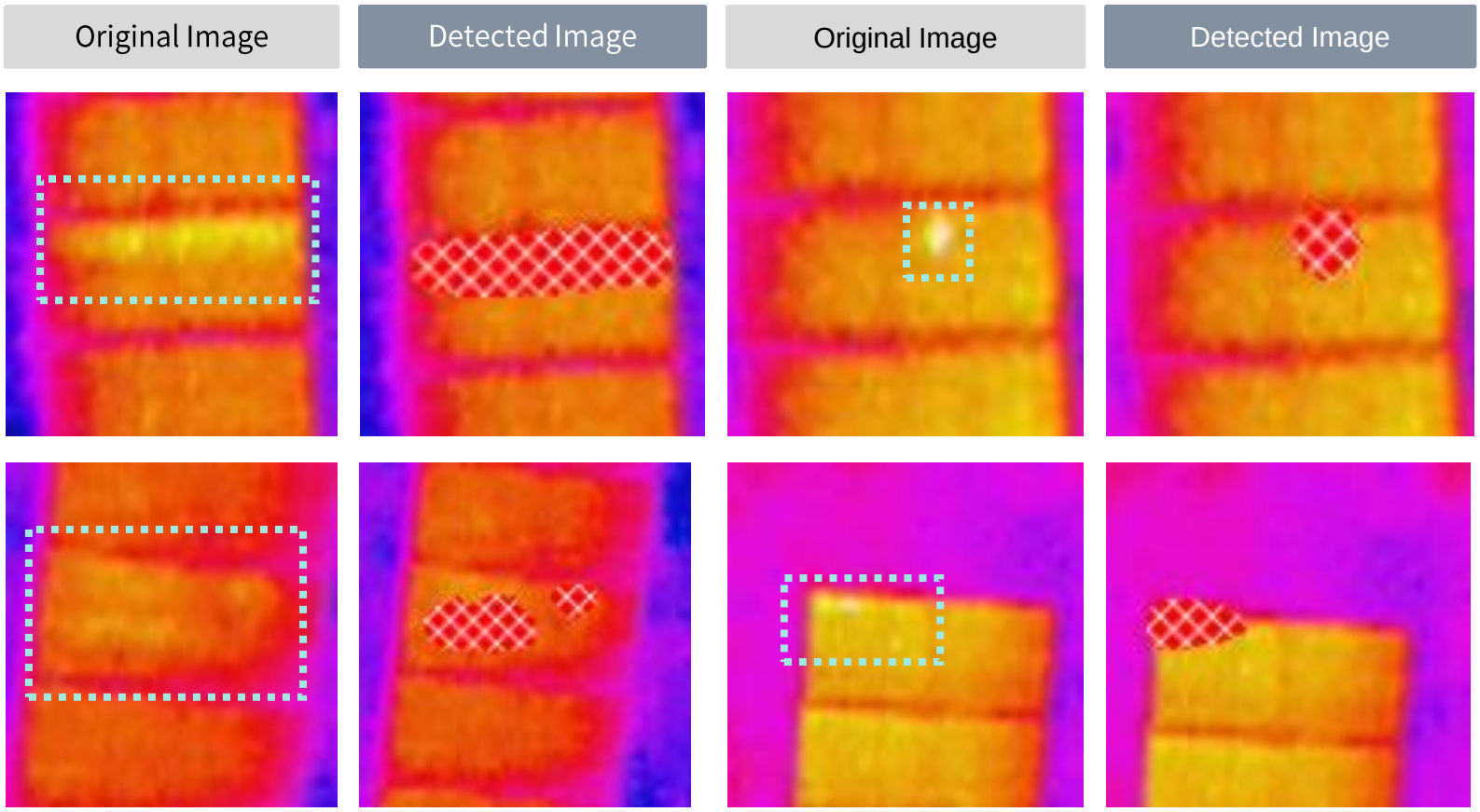


Image Analysis – 30m Above Mapping

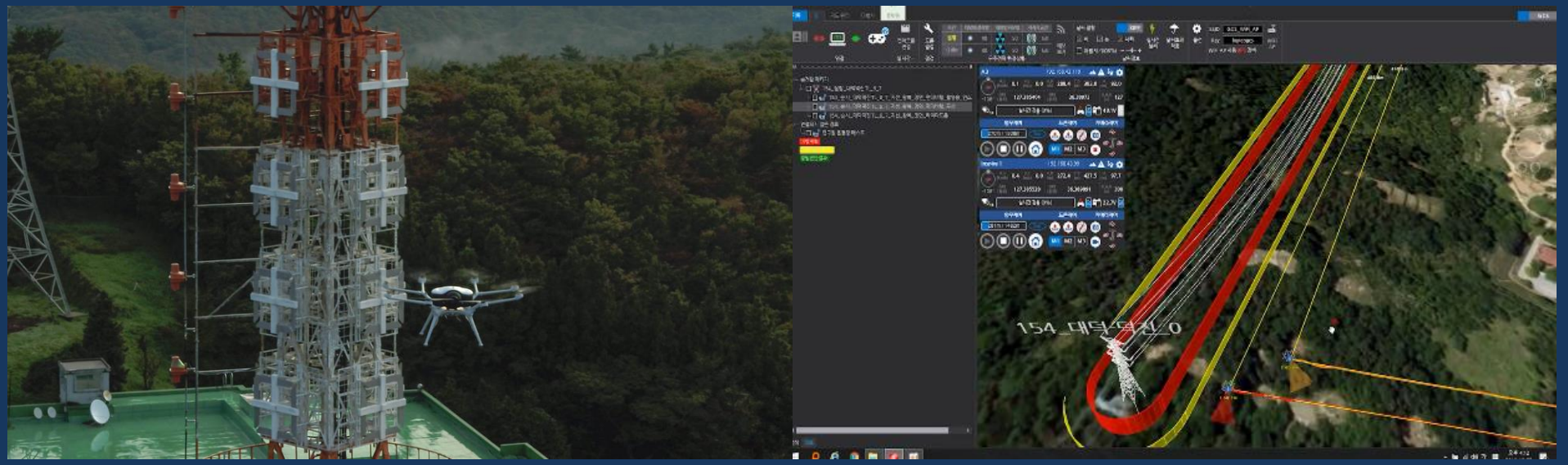
Back-up

Detected images after Machine Learning

Original Image	Detected Image

Doosan Mobility Innovation,
The Best Innovation Winner of CES 2020

Transmission Line Inspection Solution

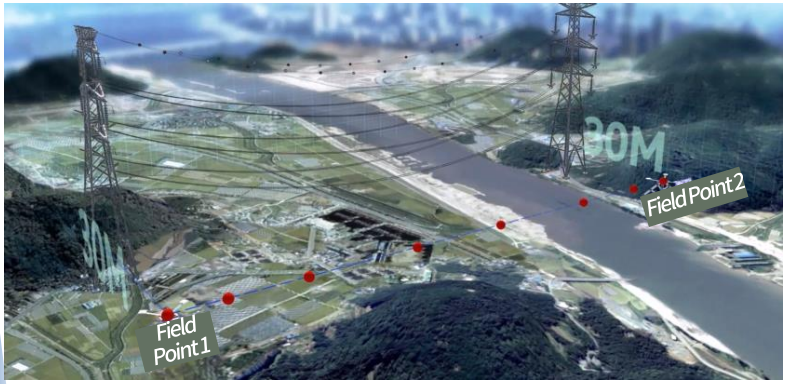


Developed and licensed with Korea Electric Power Company

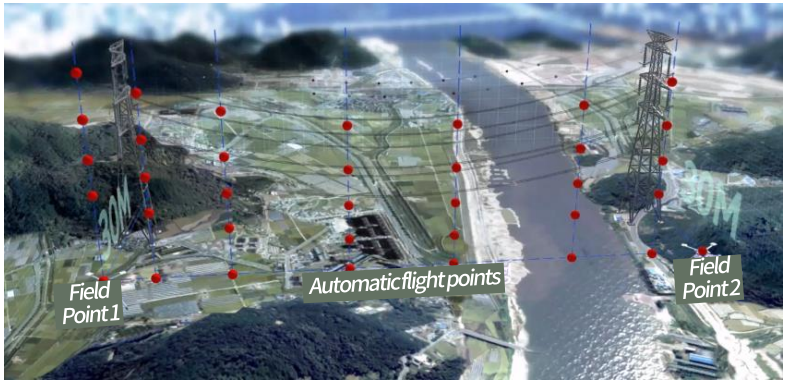
Overview of DMI's Hydrogen Drone Solution for Transmission Lines

Inspection Procedure

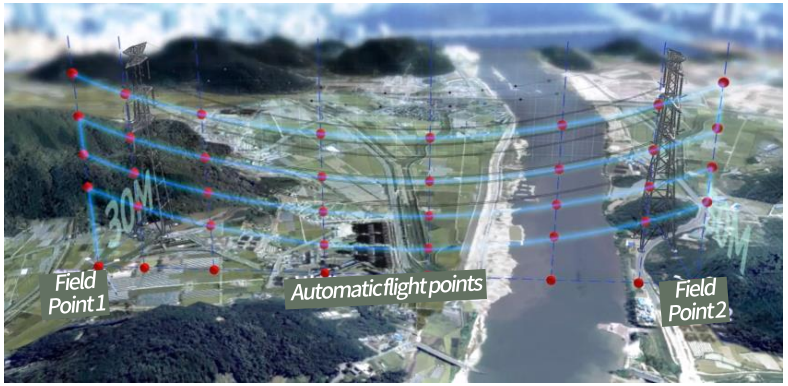
① Plan flight points that automatically maintain a safe distance of 30 meters from the lines within the GPS



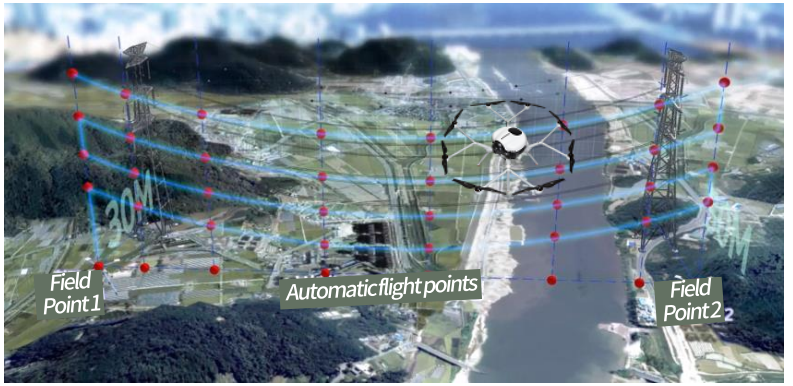
② Select the height of the flight points



③ Apply the automatic flight points into the GCS



④ Perform an automatic inspection with real-time monitoring system



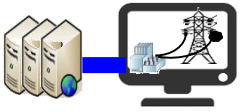
Multi-dimensional inspection solution

- Mission Control
- Operational Control
- Data Integration
- Hydrogen Supply

Technology

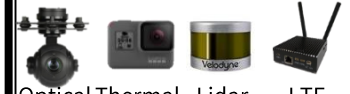
① Hydrogen Drone

② *Integrated monitoring and diagnosis System*

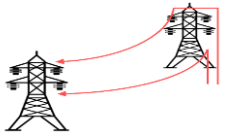


③ *Ground Control System*

④ Payloads



⑤ Formation Flight



⑥ *GPS Measuring Device*

DMI's Value Proposition for Transmission Line Inspection

DOOSAN

Specification

Type	Octocopter	**Operating distance**	Unlimited (LTE)
Size	2,600 x 2,600 x 796mm	**Wind resistance**	8m/s
Power System	Hydrogen Fuel-Cell	**Max payload**	4.5kg
Gross weight	20.4kg	**Max flight time**	120min
Maximum take-off weight	24.9kg	**Operating Temperature**	0~35℃

"The Safest, most Efficient, and most Accurate Solution for power line inspection "

Safe

Able to automatically maintain a safe distance from lines to mitigate the risk of magnetic field and automatically avoid obstacles with the rider sensor technology

Efficient

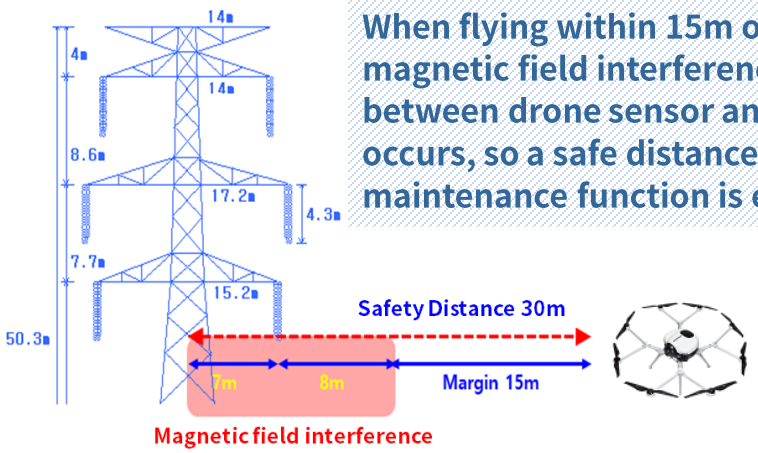
Able to inspect more than 20km of lines based on 2 hours of flight time, resulting in 6 to 8 times more efficient than battery drones, and operate multiple drones simultaneously

Accurate

Able to automatically recognize sagging lines and adjust flight altitude, resulting in obtaining the most accurate video and image information

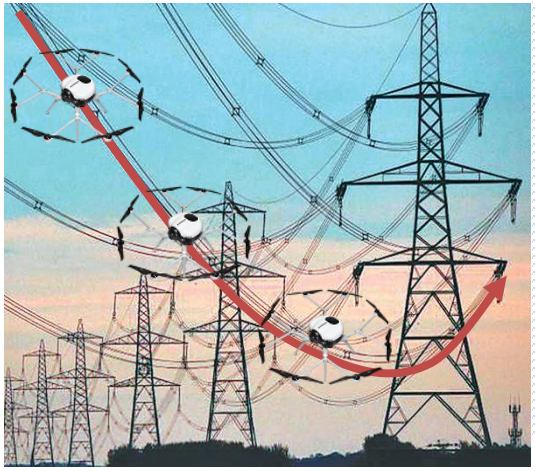
Main Technology

Automatic Safety Distance



When flying within 15m of lines, magnetic field interference between drone sensor and lines occurs, so a safe distance maintenance function is essential.

Automatic flight along the line

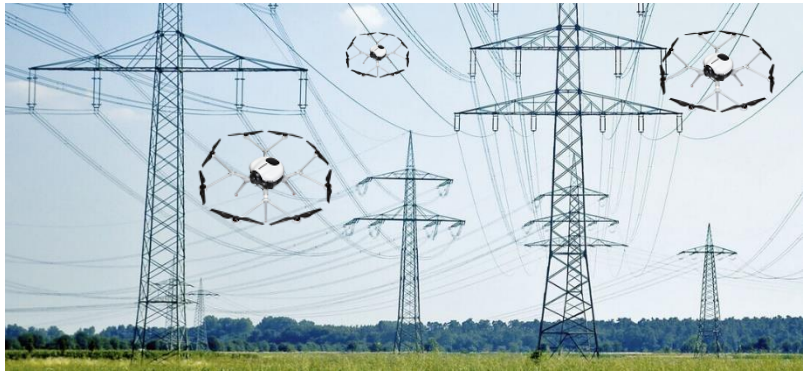


Since the power lines become sagging, the drone automatically recognizes the location of line and flies by altering its altitude according to the height of line

Automatic Obstacle Avoidance

It can automatically avoid obstacles around the lines using rider sensors to minimize the risk of collision between drones and lines

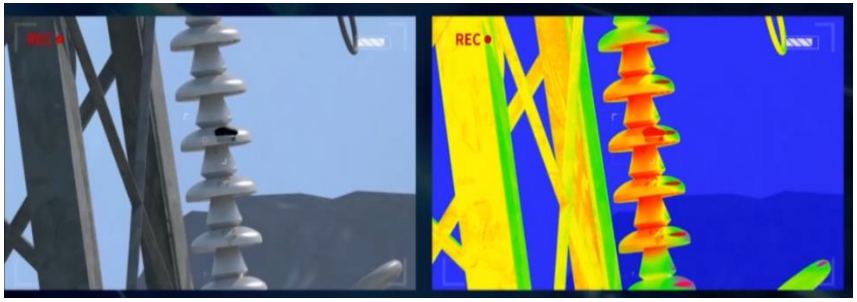
Operation and control of multi-drones



Users can operate and control multiple drones simultaneously to maximize the efficeincey

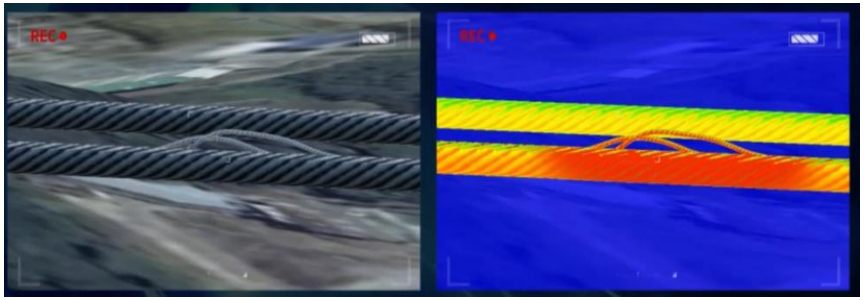
Main Inspection Factors

Punctured/Damaged Insulator



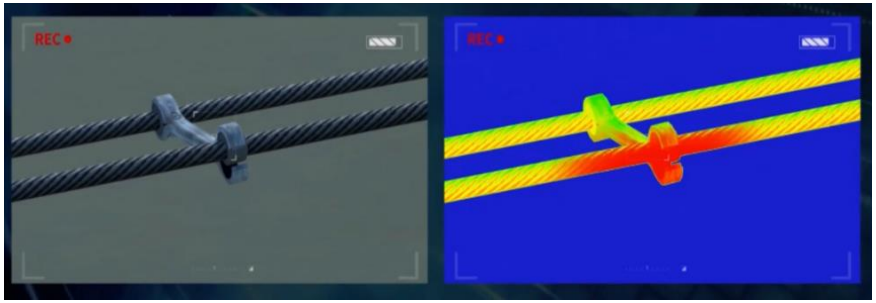
Minimize the risk of disconnection between the line conductor and the tower

Overheating and damaged lines



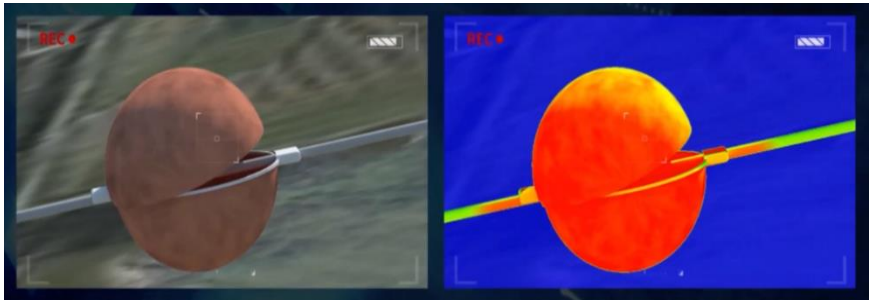
Prevent potential large-scale fire incidents

Wear of Spacer damper



Minimize the risk of vibration and sub-span oscillation

Damaged air fault indicator



Minimize the risk of collision accident of airplanes

Economic Feasibility Analysis of Transmission Line Inspection

Hydrogen drone is a more safe and economic solution compared to manpower and battery drones since it can access to remote places with minimum down time

Assumptions (Based in Korea)

Scanning & Inspection

Over-view

- Inspect status and structures of lines and towers by thermal camera
- Number of towers under inspection: 42,372개
  - Frequency: Once a year per tower
  - Inspect seven towers in two days

Assum-ptions

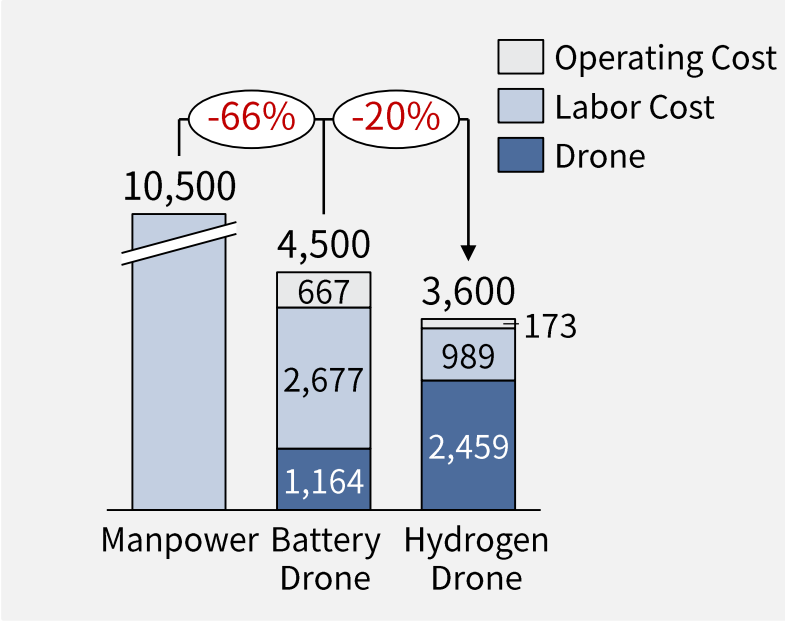
- Labor costs
  - 250 USD per towel

- Batter drone
  - Model: DJI Matrice 210
  - Price: Body($12,000), Extra Battery($1,000)
  - Number of drones required[2] : 97 units/year
  - Number of batteries required: 969 units/year

- Fuel cell drone
  - Model: DP30 + DS30
  - Price: Body($63,000) , H2($10/unit)
  - Number of drones required[2] : 39 units/year
  - Number of H2 tanks required: 19,673 units/year

Annual TCO Analysis for transmission lines

(Unit: K USD)



Benefits

- Hydrogen drones can save 66% on manpower and 20% on battery drones by optimizing labor cost and operation cost despite high initial purchase cost
- Hydrogen drones can inspect power lines in the areas that are dangerous for humans to perform or where battery drones cannot reach

1) Report from KEPCO
2) Calculation based on the number of replacements according to the life cycle of each products/parts

Pilot Application Results

Split in Connector Sleeve

Defective SB Damper

Bird Caging on Conductor

Aerial Ball Damage