Digital Transformation (DX) of Operation and Maintenance (O & M) Services Using Tools

Hiroyuki Okuda,
Shota Nakase

Keywords Drone, Autonomous flight, AI, Web camera

Abstract

As the population ages and the birthrate declines in Japan, the proportion of the working-age population responsible for society will continue to decline.

Even under these circumstances, Operation and Maintenance (O & M) services for social infrastructures are crucial to achieving a sustainable society. To efficiently maintain the facilities we give O & M services, we are promoting Digital Transformations (DX) using tools. As part of these efforts, we are conducting field testing of web-camera-based remote monitoring using Artificial Intelligence (AI) and remote inspections using unmanned aerial vehicles (drones). Advances in obstacle avoidance sensor technology have increased the reliability of drone flight, making their application to the project sites where we conduct O & M services a realistic possibility.

1 Preface

On December 5, 2022, the Aviation Act and other laws in Japan were partially revised, establishing a system for aircraft certification and type certification for unmanned aerial vehicles (hereinafter referred to as “drones”) and a national license system for drone pilots, allowing drones to fly Beyond Visual Line of Sight (BVLOS) over populated areas without assistance. The Ministry of Land, Infrastructure, Transport and Tourism is expediting legal reforms to promote the use in logistics and social infrastructure. Some of the facilities where we perform the Operation and Maintenance (O & M) services include unmanned pumping stations, and we have qualified personnel (private and national second-class drone pilot licenses). This is to make a drone-based facility inspection from the sky by remote control and for emergency response during natural disasters in the near future. This paper introduces our activities regarding the future need for drones and web-camera-based remote monitoring for future possible introduction into our O & M services.

2 Remote Aerial Inspection (Visual Drone Inspection)

2.1 Demonstration Verification of Remote Aerial Inspection

Facilities such as drainage pumping stations and other pumping stations are increasingly becoming unmanned. Until now, real people have inspected meters installed in high places, panel displays, and other instruments, including engine pumps. This time, in preparation for future unmanned operation, a demonstration test of remote aerial inspection (visual drone inspection) was conducted at a drainage pumping station. Fig. 1 shows an overview of the remote site monitoring system used in this study. The drones were remotely controlled to perform real-time remote aerial inspections.

Remote operation of drones from remote locations requires an internet connection. To establish a Wi-Fi environment within the facility, we use Starlink, which is a high-speed satellite internet service developed and provided globally by SpaceX, an American company founded by Elon Musk. This is to address the risk of communication network disruptions during disasters. This system can be used even in areas lacking in communications infrastructure. This demonstration test confirmed low latency and satisfactory operation. Fig. 2 shows the installation status of the outdoor Starlink antenna.

This allows captured data to be viewed remotely without human intervention, and data storage in the cloud allows for API (Application Programming Interface) integration with other services. If an abnormality is detected in the captured measured numerical data, an alert notification is sent, and visualization and abnormal values can be confirmed remotely.

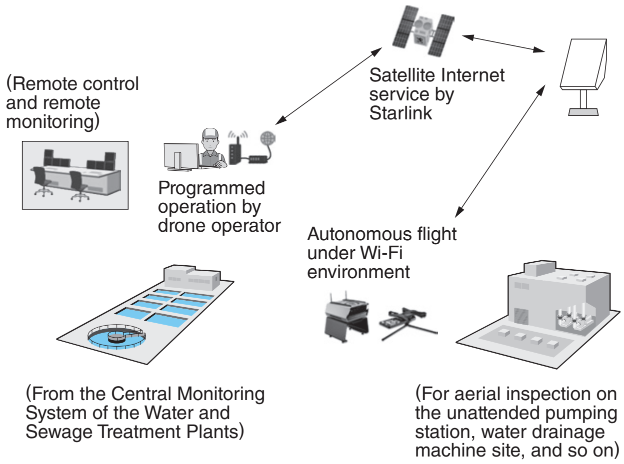


Fig. 1 **Overview of Remote Site Monitoring System Used This Time**

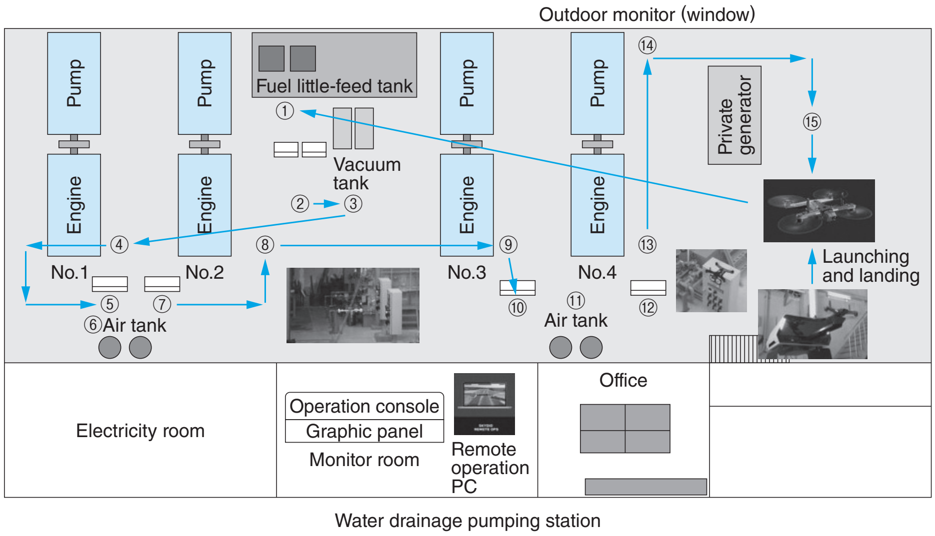
This image shows a remotely controlled drone (autonomous flight) conducting on-site and indoor aerial inspections. As a BCP measure, the drone can be used to inspect a wide area remotely during regular inspections or in the event of a natural disaster, using an internet connection via satellite.

2.2 Remotely Programmed Autonomous Flight in Enclosed Spaces and Non-GPS (GNSS)※1 Mode

Traditionally, GPS (GNSS) was required for programmed autonomous flight of drones. However, drainage and pumping stations are often indoor, enclosed spaces. The Skydio drone used in this study is a non-GPS drone that can avoid obstacles using 360-degree vision sensor camera analysis and autonomous flight using spatial awareness. Using a hangar called the Skydio Dock, remotely programmed autonomous flight is possible. Fig. 3 shows the remote aerial inspection route. The Skydio Dock functions as a drone hangar, is weatherproof (IP56) and can be installed indoors

Fig. 2 **Situation of Outdoor Starlink Antenna Installation**

This image shows the creation of an internet environment via satellite link.



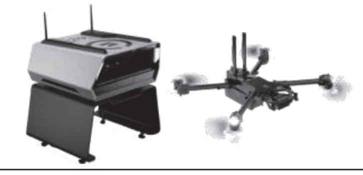
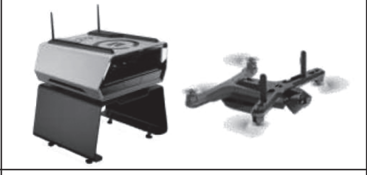
Flight route: Launching from DOC → ①Oil storage level check in fuel little-feed tank → ②Operation panel surface → ③Vacuum pump → ④No.1 engine pump meter → ⑤Operation panel surface → ⑥Air tank pressure gauge → ⑦Operation panel surface → ⑧⑨Nos.2&3 engine pump meters → ⑩Operation panel surface → ⑪Air tank pressure gauge → ⑫Operation panel surface → ⑬No.4 engine pump meter → ⑭Outdoor monitor (window) → ⑮Whole facility → Landing (charge)

Fig. 3 **Remote Aerial Inspection Route**

This image shows the drone's aerial inspection route within a drainage pumping station while avoiding obstacles.

Table 1 **Skydio Dock and Drone Specifications**

The lineups by the Skydio remote patrol system are shown.

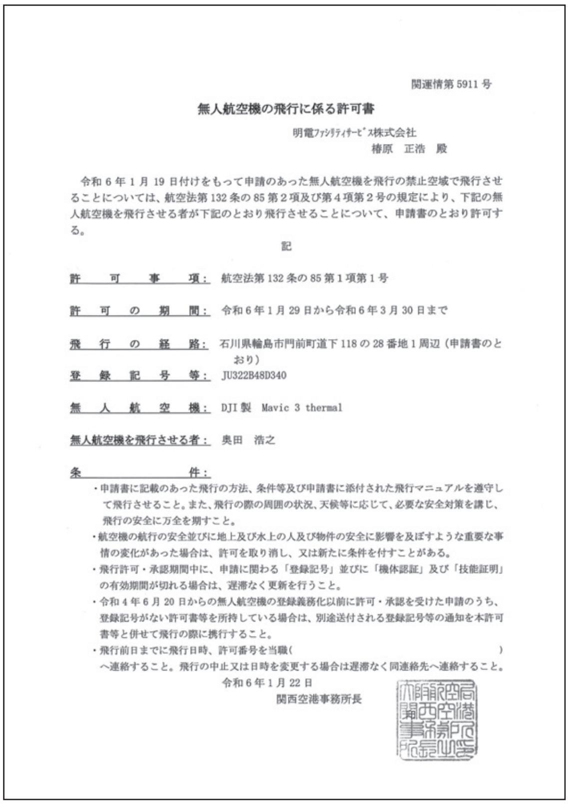
名称	Skydio Dock for X2	Skydio Dock for S2+	Skydio Dock Lite for S2+
プロダクト			
使用場所	屋外	屋内	屋内
サイズ（L×W×H）mm	ドック：64 x 62 x 31 cm 土台アンテナ含む：64 x 69 x 88.2 cm	ドック：64 x 62 x 31 cm 土台アンテナ含む：64 x 69 x 88.2 cm	ドックのみ：31 x 13 x 4.2 cm 三脚含む：31 x 13 x 12.46 cm
重量	32.7 Kg (土台無し) / 46.3 Kg (土台含む)	28.1 Kg (土台無し) / 41.7 Kg (土台含む)	0.21 Kg (クレードル) / 0.66 Kg (三脚含む)
対候性	IP56取得。粉塵や雨、雪を保護。 ドック上部に発熱体を内蔵し、積雪や 凍結に対応。加熱・冷却システムを装備。	IP規格未取得。	―
動作温度範囲	運用時： -20 - 43° C 格納時（スタンバイ）: -40 - 60° C	運用時： 0 - 35° C 格納時（スタンバイ）: 0 - 45° C	推奨施設温度： 0 - 35° C
充電時間	45分（20%-90%）	30分（20%-90%）	30分（20%-90%）2
耐風性	20ノット（23 mph, 10.3 m/s）	4ノット（2 m/s）	4ノット（2 m/s）
入力電源	1000W, 240 VAC, 50-60Hz universal input, 20 Amp 3-wire cord3	500W, 120V/240V AC, 50-60Hz universal input, IEC plug	500W, 120V/240V AC, 50-60Hz universal input, IEC plug
伝送距離	各地のWifi環境に依存します。ドローンとドックは直接通信するのではなく、現地のWifiネットワークを通じて通信します。		
Skydio Remote Ops	遠隔操縦・遠隔操作、飛行経路やミッションの作成、飛行時間の計画、リアルタイムストリーミング機能など、 Skydio Dockを使用する際に必要なソフトウェアで、初回ドック購入時に3年間の使用ライセンスがバンドルされます。		

提供：㈱ジャパン・インフラ・ウェイマーク

or outdoors. **Table 1** shows the specifications of the Skydio Dock and drone. The Dock unit integrates internet communication, drone charging, launch, landing, data processing, and other functions, enabling remote control without human intervention.

2.3 Drone Use Survey for 2024 Noto Peninsula Earthquake Damages

The magnitude 7.6 earthquake that occurred on January 1, 2024, caused extensive damages, primarily in the northern part of the Noto Peninsula which projects north into the Sea of Japan from the coast of Ishikawa Prefecture. M Winds Co., Ltd.(“M Winds”), a Meiden Group firm doing O & M services and wind farm operations, inquired about the possibility of using our drones to assess the damage to wind farm facilities where M Winds conduct O & M services. We were able to conduct a rapid on-site survey because we had obtained permission for use in emergency disasters case, as stated in the Ministry of Land, Infrastructure, Transport and Tourism (MLIT)’s “Application for Permission and Approval for Flight of Unmanned Aerial Vehicles,” which also included flight purposes for “accident and disaster response, and so on.” **Fig. 4** shows an excerpt from the application for permission and approval for flight of unmanned aerial vehicles.



関運情第 5911 号

無人航空機の飛行に係る許可書

明電ﾌｧｼﾘﾃｨｻｰﾋﾞｽ株式会社
椿原　正浩　殿

令和 6 年 1 月 19 日付けをもって申請のあった無人航空機を飛行の禁止空域で飛行させることについては、航空法第 132 条の 85 第２項及び第４項第２号の規定により、下記の無人航空機を飛行させる者が下記のとおり飛行させることについて、申請書のとおり許可する。

記

許可事項： 航空法第 132 条の 85 第 1 項第 1 号

許可の期間： 令和 6 年 1 月 29 日から令和 6 年 3 月 30 日まで

飛行の経路： 石川県輪島市門前町道下 118 の 28 番地 1 周辺（申請書のとおり）

登録記号等： JU322B48D340

無人航空機： DJI 製　Mavic 3 thermal

無人航空機を飛行させる者： 奥田　浩之

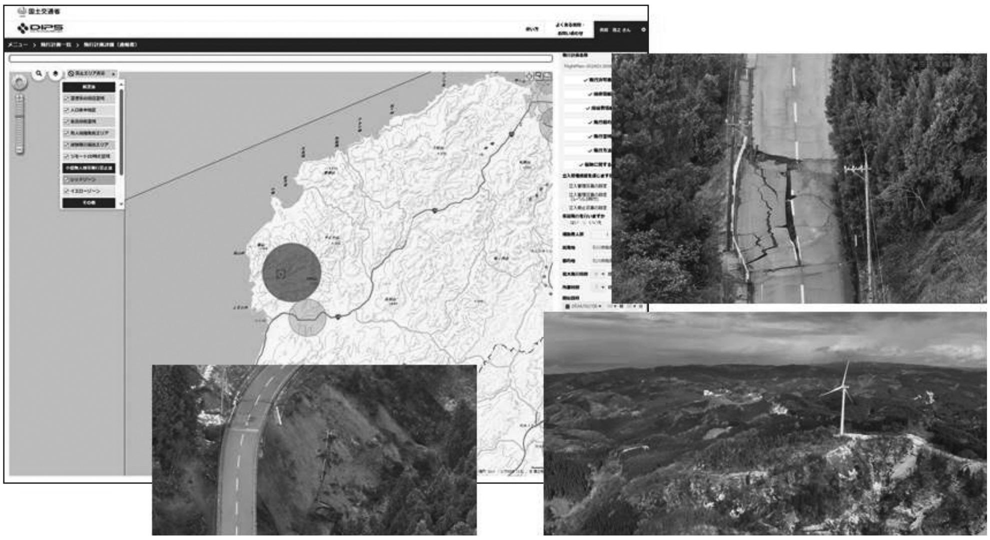
条件：

- 申請書に記載のあった飛行の方法、条件等及び申請書に添付された飛行マニュアルを遵守して飛行させること。また、飛行の際の周囲の状況、天候等に応じて、必要な安全対策を講じ、飛行の安全に万全を期すこと。
- 航空機の航行の安全並びに地上及び水上の人及び物件の安全に影響を及ぼすような重要な事情の変化があった場合は、許可を取り消し、又は新たに条件を付すことがある。
- 飛行許可・承認期間中に、申請に関わる「登録記号」並びに「機体認証」及び「技能証明」の有効期間が切れる場合は、遅滞なく更新を行うこと。
- 令和 4 年 6 月 20 日からの無人航空機の登録義務化以前に許可・承認を受けた申請のうち、登録記号がない許可書等を所持している場合は、別途送付される登録記号等の通知を本許可書等と併せて飛行の際に携行すること。
- 飛行前日までに飛行日時、許可番号を当職（　　　　　　　　）へ連絡すること。飛行の中止又は日時を変更する場合は遅滞なく同連絡先へ連絡すること。

令和 6 年 1 月 22 日
関西空港事務所長

Fig. 4 **Excerpt from Application Sheet for Approval of Drone Flight**

At the time of Noto Peninsula Earthquake occurring in 2024, the Ministry of Land, Infrastructure, Transport and Tourism specified the “Emergency Action-Taking Airspace” so that general aircraft cannot enter into this area and disaster damage restoration actions can be taken in the first preference in the disaster-stricken area. For this reason, a special approval is required when entering into this area.



Source: Cited and edited the website data on the Ministry of Land, Infrastructure, Transport and Tourism homepage
https://www.ossportal.dips.mlit.go.jp/portal/top/

Fig. 5 **Status of the Live Drone Video Streaming on Two Bases: Office at Noto Peninsula and Tokyo Head Office**

This image shows footage of roads and wind farm facility conditions being confirmed via real-time internet connection between the two bases and the project site.

Immediately after the earthquake, the airspace over the Noto Peninsula was designated an emergency airspace, prohibiting the use of general drones and radio-controlled aircraft. Upon receiving the investigation request, we immediately contacted the MLIT to confirm flight permission. We then obtained flight information from an air traffic control flight information officer. Based on advice from various organizations, we applied for permission to fly in emergency airspace in accordance with the Aviation Act. After careful consultations with the wind farm operator, Noto Community Wind Power Co., Ltd., operating at the site (Noto Peninsula), M Winds (Tokyo head office), and our company, we created a flight plan. We did live drone video streaming from the project site to M Winds head office in Tokyo and conducted the aerial investigation interactively. Here, too, Starlink enabled us to share information in real time. While infrastructure inspections are urgently needed immediately after an earthquake or disaster, sending personnel into dangerous locations carries significant risks (aftershocks and road damages). Drones, which can grasp the situation from the air, have become an important tool in these situations. Fig. 5 shows the live drone video streaming that was available to those involved in this wind farm project at two locations: the office at the Noto Peninsula and the Tokyo head office.

3 Remote Monitoring by Web Camera

3.1 Current Status of Infrastructure Facility Management and Future Measures

Our company conducts O & M services on many unmanned facilities, many of which require visual inspection. These project sites are often far from the remote monitoring office and have poor road and communication conditions. Furthermore, installing conventional surveillance cameras is expensive, limiting their adoption. By combining relatively inexpensive webcams with Starlink, we are lowering the barrier to adoption even in areas with poor communication conditions. We are promoting their adoption as a tool for real-time situation assessment, reducing walk-around inspection time, and ensuring employee safety.

3.2 Demonstration Test of Remote Monitoring Using Artificial Intelligence (AI)

Currently, small-scale water purification plants in mountainous areas do not have cameras to monitor the conditions of their intakes, where water flows in from rivers, during heavy rainfall. Therefore, the water's turbidity and other conditions are assessed and managed by human inspection. Webcams can be installed to monitor conditions such as water volume and turbidity. In case AI image analysis could be applied to camera-captured images of water vol-

Fig. 6 **Verification Test on Application of AI Camera (Example)**

This image shows a demonstration test example of the application using an AI camera: digital outputs of water condition updates footage used to quantify meters and digitally output water conditions in rivers and ponds.

ume and turbidity to detect anomalies and send alerts, capture images of chemical tanks, and calculate chemical dosages using AI analysis, such facility management could be performed from the office without on-site visits. This technology can also be implemented in cloud-computing environments and on-premises environments (where an organization hosts and manages its own hardware, software, and data locally within its own facilities). We are currently conducting field tests of AI camera-based on-site inspection in collaboration with a university startup, and we look forward to future applications. Fig. 6 shows an example of a field test using an AI camera.

Last year, we completed a field test using a general-purpose webcam to digitize the output of meter data from switchgear panel meters and instrumentation equipment and this test used AI image analysis (for web-based facility management, CSV output, and so on). Going forward, we will continue to test and develop API output from video and audio, and so on, which gives immersive virtual reality through senses. It is similar to the five human senses (vision, hearing, smell, taste, and touch).

4 Postscript

While webcams and drone cameras have traditionally been used solely for monitoring purposes, multimodal AI can now deliver digital output that attempts to mimic the very human information processing process. By associating text with images and simultaneously understanding video and audio, it aims to achieve a deeper, more contextual, and more realistic understanding than what can be achieved from a visual perception alone. The latest drones can now be equipped with environmental sensors for detecting toxic gases and oxygen levels, enabling them to be used in dangerous locations that humans cannot reach. Furthermore, by integrating them with remote-controlled autonomous robots, drones can use elevators to reach floors that drones alone cannot reach. This technology is currently undergoing demonstration testing.

Going forward, we will continue to work on introducing digital transformation tools for next-generation O & M services.

(Notes)

※1. GPS: Global Positioning System
※2. GNSS: Global Navigation Satellite System