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SERIES F: NON-TELEPHONE TELECOMMUNICATION SERVICES

Multimedia services

Requirements for inspection and examination services using civilian unmanned aerial vehicles

Recommendation ITU-T F.749.15

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Recommendation ITU-T F.749.15

Requirements for inspection and examination services using civilian unmanned aerial vehicles

Summary

Recommendation ITU-T F.749.15 specifies requirements for high-definition (HD) and virtual reality inspection and examination (IaE) services by human beings using civilian unmanned aerial vehicles (CUAVs), including those for fore-end devices capturing HD images and videos of objects and surroundings, network communication, service and application support, as well as service presentation and playback. There are many requirements for careful IaE of specific objects or facilities and surroundings, such as power lines, oil pipelines, bridges and viaducts on water and land, rivers and lakes or inspection of areas subject to emergency or disaster. With the help of HD cameras, panoramic cameras and other sensors (such as infrared sensors), a CUAV can easily accomplish IaE tasks quickly and efficiently with high quality.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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Civilian unmanned aerial vehicle, inspection and examination, requirements.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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Requirements for inspection and examination services using civilian unmanned aerial vehicles

1 Scope

This Recommendation specifies requirements for high-definition (HD) and virtual reality (VR) inspection and examination (IaE) services by human beings using civilian unmanned aerial vehicles (CUAVs), including those for fore-end devices capturing HD images and videos of objects and surroundings, network communication, service and application support, and service presentation requirements. IaE tasks completed by machine vision lie outside the scope of this Recommendation.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T F.749.12] Recommendation ITU-T F.749.12 (2020), *Framework for communication application of civilian unmanned aerial vehicles*.

[ITU-T H.264] Recommendation ITU-T H.264 (2021), *Advanced video coding for generic audiovisual services*.

[ITU-T H.265] Recommendation ITU-T H.265 (2021), *High efficiency video coding*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 civilian unmanned aerial vehicle [b-ITU-T F.749.10]: An unmanned flying device controlled by a ground control station or telecontroller via various wireless communication means. It usually consists of an aeroplane body, a power device, aviation electrical and electronic equipment and mission payload equipment, etc. and is used in non-military application areas such as industrial and consumer areas to complete the specific operation and transportation of data including audio, video and image.

3.1.2 flight control system [b-ITU-T F.749.10]: This is the sum of all components and driving devices of instruction transferring, rudder motion. It is mainly composed of airborne and ground control terminals. The one that is airborne includes three parts: airborne sensors, steering engine and flight control units.

3.1.3 ground control station [b-ITU-T F.749.10]: A ground control station is a device which is used to realize the functions of mission planning, flight control, payload control, flight path display, parameter display, image and video display and mission information displaying, recording and distributing.

3.1.4 mission payload equipment [b-ITU-T F.749.10]: The mission payload equipment consists of an audio/video/image acquisition device, signal relay device, remote electronic detection/sense device and other auxiliary devices.

3.1.5 telecontroller [b-ITU-T F.749.10]: A piece of equipment used by human beings to control an unmanned aerial vehicle. It is usually composed of an operating device, coding device, transmitting device, receiving device, decoding device and executing mechanism.

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 inspection and examination (IaE): A process to carefully check and look over specific objects / facilities and surroundings to determine whether these objects and surroundings are in a normal, damaged, dangerous or defective state.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CUAV	Civilian Unmanned Aerial Vehicle
DASH	Dynamic Adaptive Streaming over HTTP
GCS	Ground Control Station
HD	High Definition
HTTP	Hypertext Transfer Protocol
IaE	Inspection and Examination
IMT-2020	International Mobile Telecom System-2020
ISM	Industrial Scientific Medical
TV	Television
VR	Virtual Reality

5 Conventions

In this Recommendation:

– The phrase "is required to" indicates a requirement that must be strictly followed and from which no deviation is permitted if conformity to this Recommendation is to be claimed.

– The phrase "is recommended" indicates a requirement that is recommended but which is not absolutely required. Thus, this requirement needs not be present to claim conformity.

– The phrases "can optionally" and "may" indicate an optional requirement that is permissible, without implying any sense of being recommended. These terms are not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator or service provider. Rather, it means the vendor may optionally provide the feature and still claim conformity with the specification.

6 Introduction

There are many requirements for careful IaE of specific objects or facilities and surroundings to determine whether they are in a normal, damaged, dangerous or defective state. For example, IaE of hundreds of kilometres power lines and oil pipelines are needed to see whether they are aging or damaged, corroded or leaking, etc. IaE of bridges and viaducts over water and land are also needed regularly to check their appearance and structure, whether cracks exist and bridge decks, piers, abutments are damaged. The workload in these processes is not only time-consuming and laborious with a long cycle, but also very unsafe in some situations or not suitable for human beings to complete. With the help of HD cameras and other sensors (such as infrared sensors), objects or facilities can be carefully observed over the long term, or historical images or data can be compared with current images and data. CUAVs can easily accomplish inspection work quickly and efficiently with high quality. It is also necessary to observe whether any water pollution, illegal closure and occupation is affecting wide rivers, lakes and seas over long distances. This can be realized using a panoramic camera or a group of cameras deployed at certain positions carried by CUAVs. The collected data and video or images are transported back to an IaE service management system through a network and displayed or presented on an HD display screen or VR terminal.

7 Functional diagram of inspection and examination services

Based on the system requirements for IaE service in [ITU-T F.749.12], Figure 1 is a functional diagram of IaE service based on CUAV use.

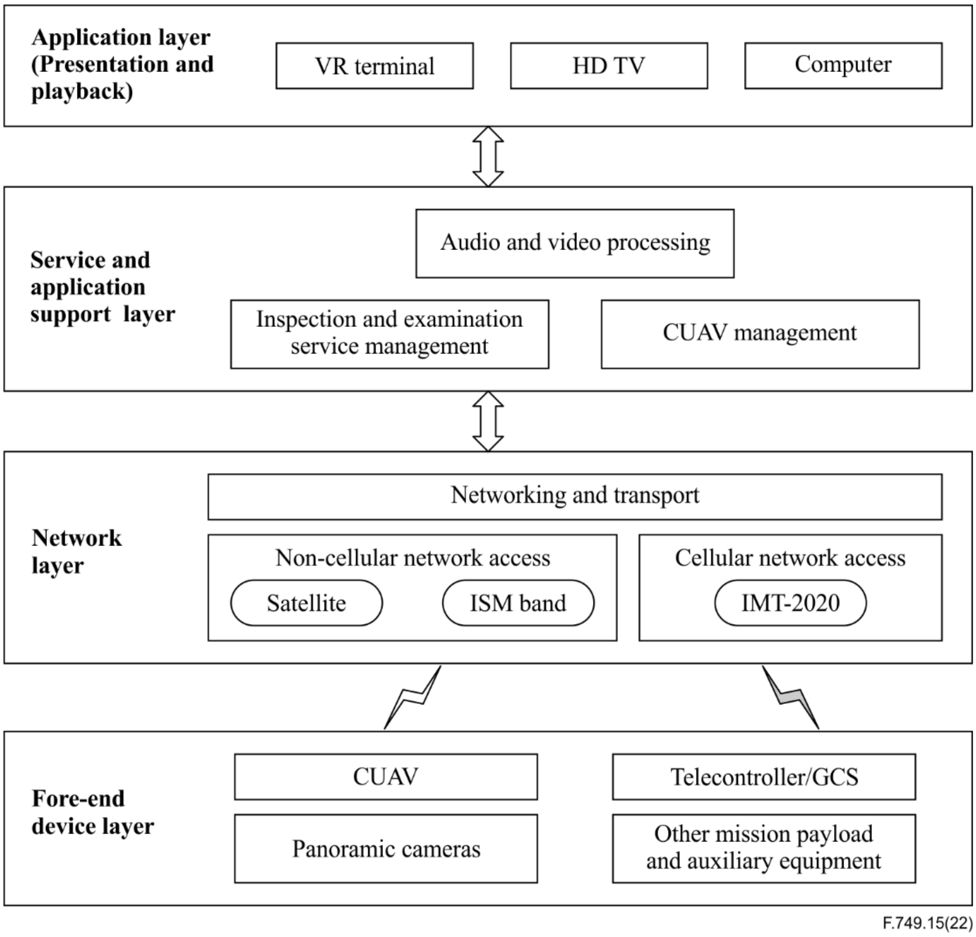

Figure 1 – Functional diagram of inspection and examination service using a civilian unmanned aerial vehicle

CUAV-based IaE service can be functionally divided into four levels: fore-end device layer; network layer; service and application support layer; and application layer. In terms of implementation methods, the whole service can be processed based on the cloud platform, including audio and video coding and decoding; alternatively, multiple sub images are spliced, projected, rotated, etc. to become a complete video or image. Finally, presentation and playback of IaE objects are completed by HD display equipment and a VR terminal.

8 Requirements for inspection and examination services

8.1 Requirements for fore-end devices

Fore-end devices include a CUAV and telecontroller/ground control station (GCS), panoramic camera as well as other mission loads and auxiliary equipment.

8.1.1 Requirements for the civilian unmanned aerial vehicle

8.1.1.1 Flight test capability

FT-01: Protection of a CUAV is required not to be lower than a certain level.

FT-02: At a higher altitude, the hovering time of a CUAV during normal operation is required not to be less than 20 min.

FT-03: A CUAV is required to fly stably under light rain conditions, and the flight time to be not less than a certain value.

FT-04: A CUAV is required to work and hover normally under the environmental conditions of instantaneous wind speed not greater than 10 m/s (level 5 wind).

FT-05: During a self-inspection test, a CUAV is required to give alarm prompt (e.g., sound or light signal or other means), and the flight control system is locked.

8.1.1.2 Flight performance and function

FP-01: A CUAV is required to communicate and interact with the telecontroller or GCS to complete the its flight and state control, and can transmit the data, video or images obtained by mission payload devices back to the IaE service management system.

FP-02: A CUAV is required to transport flight data (including flight altitude, speed, flight trajectory coordinates, flight attitude, residual energy and flight time) to the GCS and IaE service management system.

FP-03: When a CUAV loses the remote control signal, it is required to support automatic hovering, calculate the best return route after exceeding the given time, and automatically return and land.

FP-04: The deviation of navigation and positioning is recommended to not be greater than 1.5 m in the horizontal direction and 3 m in the vertical direction.

FP-05: Hovering control deviation is recommended to be no more than 1.5 m in the horizontal direction with a standard deviation of no more than 0.75 m, and no more than 2 m in the vertical direction with a standard deviation of no more than 1 m.

FP-06: When the flight speed exceeds 5 m/s, a CUAV is required to detect obstacles such as conductors and towers, within a 20 m radius.

8.1.2 Requirements for the telecontroller/ground control station

The functions of a flight controller (including telecontroller and mobile phone) and GCS shall support the operation and control of a CUAV, including cruise flight control, mission specific flight control and landing (return), complete flight status monitoring, operation mode switching, fault diagnosis and processing.

8.1.2.1 Telecontroller

TE-01: A telecontroller is required to remotely control the CUAV within the visual range, and international mobile telecom system-2020 (IMT-2020) network or an industrial-scientific-medical (ISM) band can be selected to control the CUAV.

TE-02: A telecontroller is required to have its own flight display screen to support the display of the CUAV flight trajectory on an electronic map, and be able to control the flight direction, flight speed, take-off and landing of the CUAV.

TE-03: A telecontroller is required to operate and control the mission payload equipment to complete specific flight tasks, and can be set according to requirements to display the audio and video or images captured by the mission payload and the data obtained by the sensors on the display screen.

TE-04: A telecontroller is required to display its remaining power and the remaining flight time of the CUAV.

8.1.2.2 Ground control station

GCS-01: A GCS is required to integrate and display flight parameters and mission parameters, which can be used by operators to analyse and judge the flight status of a CUAV and the status of mission load equipment. Also, a GCS can remotely operate and control the payload equipment carried by a CUAV to complete the mission tasks.

GCS-02: A GCS is recommended to support the automatic or manual generation of a task plan.

GCS-03: A GCS is required to display flight heading and track parameters in real time, including flight altitude, speed, flight track coordinates, flight attitude, flight time and navigation parameters of a CUAV. It is required to support set waypoint parameters and routes on the map (the number of editable waypoints to be not less than 50). It is required to support the function of automatic map roaming, scheduled flight track and real-time flight track display of a CUAV.

GCS-04: A GCS is required to support multiple flight control modes for different environments. When the control signal is disturbed, "one key" return command shall be supported.

8.1.3 Requirements for the generation of panoramic views

There are two ways of generating panoramic views. The first deploys a group of cameras at certain positions, and the field of view can be 180° or 360°. The original images collected by these wide-angle cameras are processed by software to eliminate some distortions, and then a panoramic video is synthesized according to the visual habits of the human eye. The second is the panoramic camera. Users can choose either according to their requirements and the application scenario.

8.1.3.1 Multi cameras acquisition and synchronization

AS-01: It is recommended that the number of cameras be between four and eight, and each channel correspond to one video stream, and select one channel with its video stream and audio stream (on-site pickup) synchronization. Control the cameras to power on and start synchronously to keep the interframe error of the multi-channel stream as small as possible (< 100 ms). If the synchronization error of multi-channel video continues to expand after long time streaming, it needs to be calibrated regularly.

8.1.3.2 Panoramic camera

PC-01: It is recommended that a panoramic camera adopt internal system on chip splicing, and support three-dimensional noise reduction as well as ITU-T H.264 coding baseline/main profile/high profile, ITU-T H.265 coding main profile.

PC-02: It is recommended that mainstream frame rate and resolution support 50 to 60 frames/s or 20 to 30 frames/s and 3840*2160, 1920*1080 and 1280*720, respectively. If a substream is enabled, then 20 to 30 frames/ s and 1280*720, 640*480 and 320*240, respectively.

8.1.4 Requirements for other mission payload and auxiliary equipment

The IaE equipment carried by a CUAV includes the following types, which can be selected according to actual requirements.

MP-01: An HD camera is recommended to meet the application scene requirements of resolution, field angle, etc. Video and audio encoding and decoding technologies such as those specified in [ITU-T H.264] and [ITU-T H.265] are recommended, supporting frame rate and resolution of 50 to 60 frames/s or 20 to 30 frames/s and 3840*2160, 1920*1080 and 1280*720, etc., respectively.

MP-02: An infrared camera is recommended to meet the application scene requirements of working wavelength, resolution and automatic focusing, etc. It is recommended that the effective count shall not be less than 300 kpixel, and the image taken at a distance of not less than 10 m can clearly identify the fault hot spot.

MP-03: It is recommended that payload equipment be remotely controlled for switching, recording, amplification, focusing, aperture, etc., and supporting the adjustment of pan/tilt/zoom, horizontal rotation speed and reverse direction.

8.2 Requirements for network communication

A CUAV-based IaE service is required to use a wireless communication network to control CUAV flight and remotely operate the mission payload as well as transport audio and video. Wireless networks are required to have high bandwidth and low delay, and provide relevant control and resource reservation of network connection, access and transmission resource control, mobility management or authentication, authorization and accounting. Multiple wireless communication modes are required between a CUAV and telecontroller/GCS to maintain uninterrupted, real-time and reliable communication and transport. Means such as IMT-2020, ISM band and satellite can be used to control CUAV flight and transport data and audio or video information obtained by the mission payload.

8.2.1 Requirements for networking and transport

NT-01: Network and transmission functions are required to support real-time and reliable flight control and flight data transport. Before transport service starts, it is necessary to establish secure transport channels for data and audio and video images, and conduct two-way authentication.

NT-02: When IMT-2020 and ISM bands are used, the image transport bandwidth is recommended to be > 2 Mbit/s and the image transport delay <1 s. The data transport delay is < 500 ms, and the bit error rate is $\leq 1 \times 10^{-6}$.

8.2.2 Requirements for non-cellular network access

NC-01: A non-cellular network can optionally support using satellite to access and transport application data and video or images.

NC-02: It can optionally support the use of an ISM frequency band for flight control communication of CUAV and audio and video data transport.

8.2.3 Requirements for cellular network access

CN-01: Establishment of a direct command and control link is required to support the CUAV controller and CUAV to communicate with each other and both are registered on the IMT-2020 network using a radio resource configured and scheduled provided by that network for their communication.

CN-02: Support for the CUAV controller and CUAV register is required, as well as establishment of the corresponding unicast command and control communication links to the IMT-2020 network. Also, both the CUAV controller and CUAV may be registered on the IMT-2020 network via different radio access network nodes. The IMT-2020 network needs to support a mechanism to handle the reliable routing of communication.

CN-03: It is recommended that CUAV controllers based on IMT-2020 network can support control of one or more CUAVs.

8.3 Requirements for service and application support

The audio or video images and data obtained by fore-end devices are processed, and the corresponding objects or facilities and surroundings directly presented on the given interface (such as an HD television (TV) screen and computer screen). The inspector judges the state of these objects, or the inspector can see the surroundings all-round through VR glasses to experience the environment and objects.

8.3.1 Audio and video processing

Videos and images captured by HD and infrared cameras can be viewed in real time or replayed at the back end.

8.3.1.1 High-definition video

VI-01: High-definition video is required to support audio and video storage in mainstream formats.

VI-02: High-definition video is recommended to adopt video and audio coding technologies such as those specified in [ITU-T H.264] and [ITU-T H.265] for encoding and decoding formats, as well as support for frame rate and resolutions such as 50 to 60 frames/s or 20 to 30 frames/s and 3840*2160, 1920*1080 and 1280*720, respectively.

VI-03: For the same input, high-definition video can optionally support output of multi-rate code streams (4K, 1080P and 720P) at the same time.

8.3.1.2 Synthesis of multi view video or audio as a panoramic video

SY-01: It is recommended first to receive the video and audio data collected by the fore-end devices and to save them. Second the streaming server is required to complete the splicing, projection, rotation, etc. of multiple sub images to become a complete video or image, and the audio data is encoded directly. According to the configuration of the terminal, multi view video rendering can also be achieved on the streaming server to reduce the requirements on the VR terminal. Finally, the encoded video and audio data are encapsulated in the streaming server. The packaging format and storage format of multi view video is recommended to support MP4 and dynamic adaptive streaming over hypertext transfer protocol (HTTP) (DASH), etc.

8.3.2 Inspection and examination service management

CUAV-based IaE can generally be divided into daily IaE, dedicated IaE or construction status IaE.

Daily IaE: It is recommended that daily IaE can conduct a large-scale, non-stop inspection based on pre-set route flight, and save the obtained data and video on the IaE server. The inspector can check and compare in real time or review, summarize and mark these data or images for further inspection and verification.

Dedicated IaE: It is recommended that for key locations and parts, suspicious points found in daily IaE, local special IaE can be carried out for rapid inspection, disposal and decision-making, such as obtaining evidence for certain behaviours and events (e.g., oil theft) or early warning (e.g., about pipeline or tank temperature, accurate location of leakage point or rapid fire detection).

Construction status IaE: It is recommended that construction status IaE can finish construction information collection, construction progress management, construction supervision of power lines or oil pipelines and bridges, etc.

SM-01: It is recommended each time to record the flight process, including flight speed, flight altitude and route, through continuous optimization and adjustment, so as to set the best route, flight altitude and speed for the next IaE service.

SM-02: It is recommended that the IaE service management system shall be able to convert inspection results (including normal status, aging, damage degree and water quality level) into file data and generate an IaE report.

SM-03: It is recommended that the IaE service management system shall be able to give action suggestions for aging, serious damage or danger, etc. such as immediate maintenance or dedicated IaE for confirmation according to IaE report results.

SM-04: It is recommended that the IaE service management system shall be able to make statistical analysis on the historical data of the inspection results and predict the change trend (e.g., of water quality and cracks), so as to provide reference for later maintenance and treatment.

8.3.3 Civilian unmanned aerial vehicle management

A CUAV shall be certified and authorized by the management department (e.g., of the national civil aviation authority or international civil aviation organization) before its flight, and meet its local flight supervision requirements. A CUAV can receive the latest flight notice and electronic map data of flight-prohibition zones, densely populated areas and airports from the management department, save the current flight data to the database server, and send the updated notice and data to the CUAV flight control system.

CM-01: It is recommended that CUAV management shall provide function to register CUAV information (including its registration number, communication module identifier, model, and flight control equipment number and category) before the first flight. The national registration number is unique and traceable.

CM-02: It is recommended that a flight control system shall support real-time flight warning in a flight-prohibition zone and densely populated area. If a CUAV flies close to or enters electronically fenced areas, then immediate warning shall be sent to users (e.g., notifying them of illegal flights with time and locations).

8.4 Requirements for service presentation and playback

According to different application scenarios and requirements, the video or images obtained by HD cameras (including single channel and multi-channel) and infrared cameras can be presented through HD display equipment for inspectors to view. The view can be divided into real-time view and review. The images obtained by a multi-channel or panoramic camera can also be synthesized and viewed through a VR terminal.

8.4.1 Requirements for a virtual reality terminal

A VR terminal mainly includes several modules such as access engine, unpacker, decoder, renderer and sensor (such as inertial sensor and geomagnetic sensor), which complete the acquisition of user motion signal and window metadata, as well as the unpacking, decoding and rendering of VR media content.

VR-01: It is required that a VR terminal request VR media service from a streaming server and downloads an index file and omnidirectional media fragment file. The compressed video data and audio data are obtained by unpacking, and then the compressed data are decoded by video decoder and audio decoder, respectively. Finally, combined with the window metadata, the decoded video data is projected, rotated and rendered, and the decoded audio data is directly rendered, and all presented to the viewer.

VR-02: It is recommended that a VR terminal support a universal serial bus interface, wireless fidelity or Bluetooth to connect to a streaming server.

8.4.2 Requirements for the high-definition display device

HD display equipment includes an HD TV and computer, which supports HD and 4K display, frame rates of 50 to 60 frames/s or 20 to 30 frames/s and 3840*2160, 1920*1080 and 1280*720 resolutions. It is recommended to support real time streaming protocol, MP4, DASH formats, 4:2:2 and 4:2:0 live broadcast and review, with pause, fast forward or rewind operations. For multi-channel cameras, it is recommended to support switching to any channel for viewing.

HD-01: It is required to clearly display the status of power lines, insulators, iron towers and other components. It is required to support the positioning and zoom view of whether the power line is aging or damaged, and whether screws are loose, rusted or dirty.

HD-02: It is required to clearly display the status of a bridge deck, pier, tower column, cable, tower top lightning rod, etc. It is required to support the zoom view of whether the main components of the bridge have cracks or damage, exposed steel bar corrosion, bolts falling off, etc.

HD-03: It is required to clearly display an oil pipeline and its surrounding status, and support the identification and inspection of whether the oil pipeline is damaged, corroded or leaking.

HD-04: It is required to clearly display the water surface and water facilities of rivers, lakes and wetlands.

HD-05: It is required to clearly display the on-site status of natural disasters and support zoom view of drought, forest fire, flood, landslide, earthquake, etc., and to find whether there are survivors at an emergency or disaster site.

HD-06: It is required to clearly display the status of an industrial disaster site and support the zoom view of chemical plant and nuclear power plant facilities and surroundings.

Appendix I

Examples of high-definition and virtual reality inspection and examination services using civilian unmanned aerial vehicles

(This appendix does not form an integral part of this Recommendation.)

Figure I.1 shows the general process of HD and VR IaE service using CUAV, including fore-end devices capturing HD images and videos of objects and surroundings, uploading images or data via networks, subsequent data processing, finally, HD images and video presented and displayed for inspection.

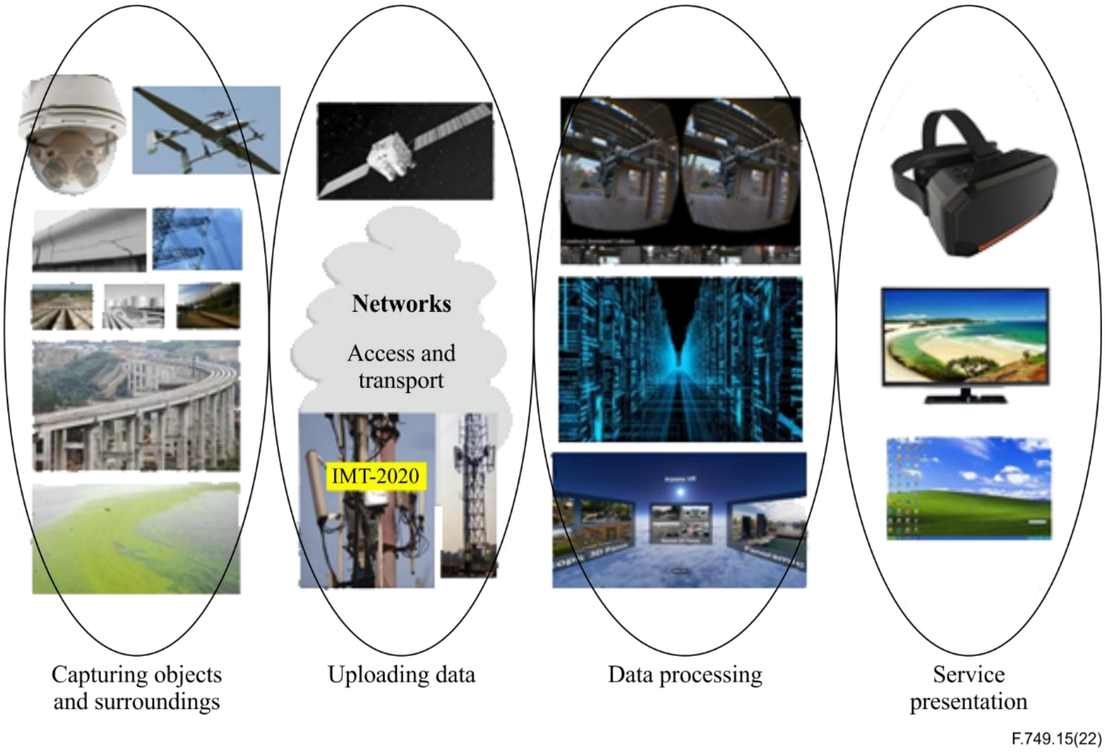

Figure I.1 – The general process of high-definition and virtual reality inspection and examination services using civilian unmanned aerial vehicles

Some examples and scenarios of IaE services follow. See Figures I.2 to I.5.

For hundreds of kilometres power lines, clear vision of their status, as well as insulators, iron towers and other components, is needed to determine whether the power line is aging or damaged, and whether screws are loose, rusted or dirty.

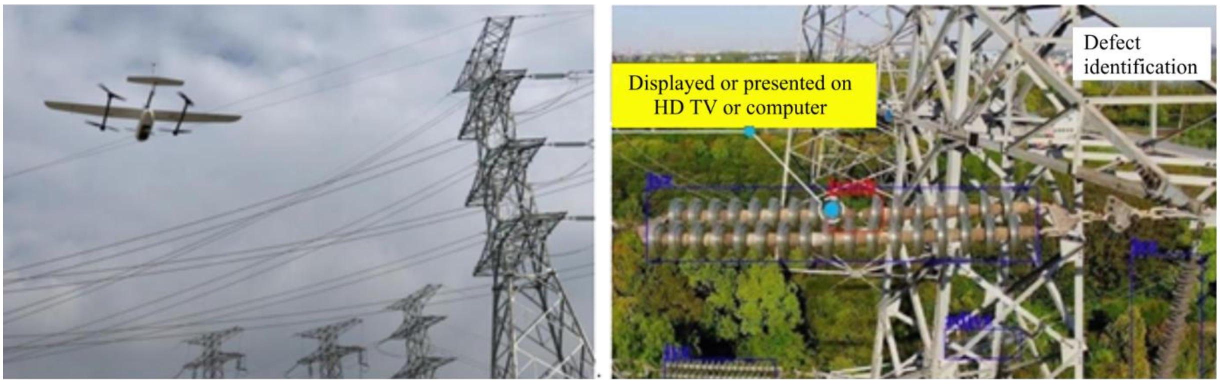

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Figure I.2 – Example of power lines and its supporting facilities inspection and examination service

For hundreds of kilometres oil pipelines as well as their supporting facilities, inspectors can clearly see whether installations are aging or damaged, corroded or leaking, etc.

F.749.15(22)

Figure I.3 – Example of oil pipelines and its supporting facilities inspection and examination service

For bridges and viaducts over water and land, an inspector can clearly look over the main components to establish whether the bridge has cracks or damage, exposed steel bar corrosion, bolts falling off, etc.; an inspector can also regularly inspect and evaluate their appearance and structure.

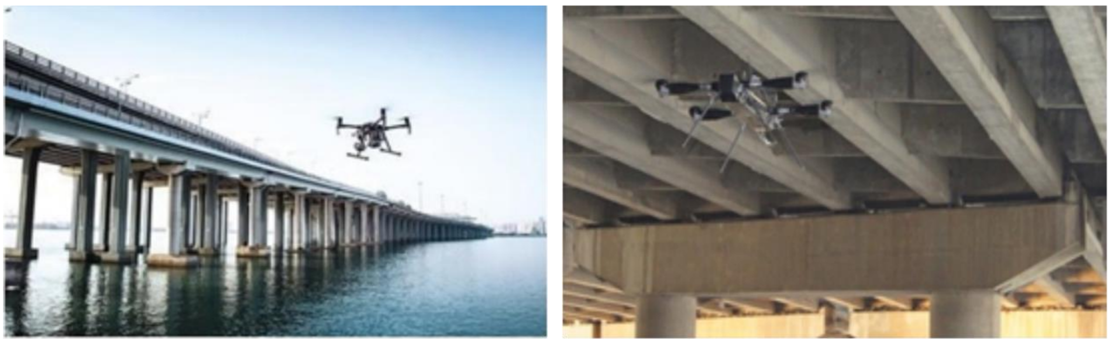

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Figure I.4 – Example of bridges and its supporting facilities inspection and examination service

For wide rivers and lakes over long distances, the inspectors can electronically survey the scene via a VR panoramic camera to observe the water surface and water facilities of rivers, lakes and wetlands.

Figure I.5 – Example of rivers and its surroundings IaE service

Bibliography

[b-ITU-T F.749.10] Recommendation ITU-T F.749.10 (2019), *Requirements for communication services of civilian unmanned aerial vehicles*.

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