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HSTP-DIS-UAV **Use cases and scenarios for disaster information service using unmanned aerial vehicles**

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Summary

This technical paper describes use cases and scenarios for disaster information service using unmanned aerial vehicles (UAV). UAVs are expected to be applicable to various disaster situations such as drought, fire, flood, landslide, earthquake, volcanic eruption, tsunami, etc. Use cases in all disaster phases are described, including preparedness phase (before disaster), response and relief phase (during disaster), recovery and reconstruction phase (after disaster).

Keywords

Disaster monitoring; disaster preparedness; disaster response; disaster relief; unmanned aerial vehicle; early warning system.

Change Log

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Technical Paper ITU-T HSTP-DIS-UAV

Use cases and scenarios for disaster information service using unmanned aerial vehicles

1 Scope

This technical paper addresses use cases and scenarios of disaster information service using unmanned aerial vehicles (UAV) for the various disaster situations such as drought, fire, flood, landslide, earthquake, volcanic eruption, and tsunami. Use cases in all disaster phases are described, including preparedness phase (before disaster), response and relief phase (during disaster), recovery and reconstruction (after disaster).

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3 Terms and definitions

3.1 Terms defined elsewhere

This Technical Paper uses the following terms defined elsewhere:

3.1.1 disaster [UNISDR Terminology]: A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.

3.1.2 disaster preparedness [FG-Term]: The state of having been made ready or prepared to counter the effects of a natural hazard (e.g. earth quake, tsunami).

3.1.3 disaster relief [FG-DR]: Information or action designed to be effective for reducing, suppressing, or avoiding impacts caused by disaster.

NOTE – The disruption may be caused by accidents, natural phenomena or human activity, and results in a significant widespread threat to human life, health, property or the environment.

3.1.4 disaster relief phase [FG-Term]: The disaster relief phase describes the time period for immediate response after a disaster has occurred to overcome the immediate effects of the disaster.

NOTE – Such relief work includes providing food, clothing, shelter, and medical care to victims. Emergency communication links for connecting people to each other and conveying damage status information are most important. For disasters, such as earthquakes or tsunamis this phase may last for weeks or months.

3.1.5 disaster relief radiocommunication [FG-Term]: Radiocommunication used by agencies and organizations dealing with a serious disruption of the functioning of society, posing a significant, widespread threat to human life, health, property or the environment, whether caused by accident, nature or human activity, and whether developing suddenly or as a result of unexpected complex, long term process.

3.1.6 disaster restoration phase [FG-Term]: The restoration phase covers efforts to establish evacuation shelters for people, to restore the administrative functions of local communities, and to rebuild the basic infrastructure of daily life.

3.1.7 disaster relief system [FG-DR]: A system that supports related parties including victims, rescue workers.

3.1.8 disaster response [UNISDR Terminology]: The provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected.

NOTE – Disaster response is predominantly focused on immediate and short-term needs and is sometimes called “disaster relief”. The division between this response stage and the subsequent recovery stage is not clear-cut. Some response actions, such as the supply of temporary housing and water supplies, may extend well into the recovery stage.

3.1.9 disaster risk [UNISDR Terminology]: The potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period.

3.1.10 disaster risk management [UNISDR Terminology]: The systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster.

3.1.11 disaster risk reduction [UNISDR Terminology]: The concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters,

including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events.

3.1.12 early warning system [UNISDR Terminology]: The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss.

NOTE – This definition encompasses the range of factors necessary to achieve effective responses to warnings. A people-centred early warning system necessarily comprises four key elements: knowledge of the risks; monitoring, analysis and forecasting of the hazards; communication or dissemination of alerts and warnings; and local capabilities to respond to the warnings received. The expression “end-to-end warning system” is also used to emphasize that warning systems need to span all steps from hazard detection through to community response.

3.1.13 preparedness [UNISDR Terminology]: The knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions.

3.1.14 prevention [UNISDR Terminology]: The outright avoidance of adverse impacts of hazards and related disasters.

3.1.15 sensor [ITU-T Y.2221]: An electronic device that senses a physical condition or chemical compound and delivers an electronic signal proportional to the observed characteristic.

3.1.16 service [ITU-T Y.2221]: A set of functions and facilities offered to a user by a provider.

3.1.17 visual surveillance [ITU-T F.743]: A telecommunication service focusing on video (but including audio) application technology, which is used to remotely capture multimedia (such as audio, video, image, alarm signals, etc.) and present them to the end user in a friendly manner, based on a managed broadband network with quality, security and reliability ensured.

3.2 Terms defined here

None.

4 Abbreviations

CCD	Charge-Coupled Device
CMOS	Complementary Metal-Oxide-Semiconductor
DEM	Digital Elevation Model
InSAR	Interferometric Synthetic Aperture Radar
SAR	Synthetic Aperture Radar
UAV	Unmanned Aerial Vehicle
UNISDR	United Nations International Strategy for Disaster Reduction (United Nations Office for Disaster Risk Reduction)

5 Conventions

None.

6 Overview

Disaster information services are used for disaster detection, relief, and recovery. An effective disaster information service can save lives and reduce economic losses. Constructing a disaster

information service is an important aspect of disaster preparedness. [ITU-R RS.1859] provides guidelines on the use of satellite-provided remote sensing data in the event of natural disasters and similar emergencies. The visual surveillance system, which is described in [ITU-T F.743], can be used for disaster monitoring. Ubiquitous sensor network applications and services described in [ITU-T Y.2221] can be used for the early detection of disasters. Monitoring systems in [ITU-T L.81] uses sensor networks to mitigate damage and to secure outside plant facilities against disasters. However, conventional means of disaster monitoring like satellites and fixed remote cameras have a number of limitations including high cost, low temporal resolution, and low spatial resolution. The UAV technology has potential to augment traditional disaster information services by overcoming those limitations.

Procurement and operational costs of UAVs are lower than those of manned aircrafts while providing similar level of collection of surveillance information. Comparing to the satellites-based remote sensing approach, UAVs can provide up-to-date higher spatial resolution images. In short, UAVs with adequate sensors can be effectively used for disaster detection, disaster response, disaster restoration, and other activities.

This technical paper describes use cases and scenarios for disaster information services using UAVs. UAVs are expected to be applicable to various disaster situations such as drought, fire, flood, landslide, earthquake, volcanic eruption, tsunami, etc. Use cases are described in all disaster phases, which are preparedness phase (before disaster), response and relief phase (during disaster), recovery and reconstruction phase (after disaster).

6.1 Sensors for disaster information service

The following sensors can be used for disaster information services using unmanned aerial vehicles.

- **Visible light camera (visible-band camera):** digital cameras are used for capturing images in the visible spectrum, which is the portion of the electromagnetic spectrum that is visible to the human eye. A typical digital camera uses a CCD or CMOS image sensor with a colour filter array and an infrared cut-off filter.
- **Thermographic camera:** a thermographic camera, which is also called a thermal imaging camera or infrared camera, captures thermal images using infrared radiation. The thermal images contain apparent temperature measurements for each pixel.
- **Multispectral camera:** a multispectral camera captures image data at several spectral frequencies across the electromagnetic spectrum. One digital image is acquired for each small spectral band, which represents a wavelength range of the electromagnetic spectrum. Near infrared, middle infrared, and far infrared bands are often used with red, green, and blue bands.
- **Hyperspectral camera:** a hyperspectral camera produces image data for hundreds of continuous bands across the electromagnetic spectrum. The spectral bands in hyperspectral imagery are much narrower (10-20 nm) than those in multispectral imagery. In hyperspectral imagery, the spectral bands cover a continuous spectral range.
- **LIDAR:** LIDAR is a remote sensing technology that measures a distance by illuminating a target with a pulsed laser and analysing the reflected light. When a UAV with a LIDAR sensor flies over a specific area, three-dimensional information about the shape of the area and its surface characteristics is obtained. The information can be used to create a DEM.
- **SAR:** a synthetic aperture radar is a class of side-looking radar that utilizes the flight path of the platform to simulate a large antenna or aperture electronically. The simulation enables to provide finer spatial resolution than is possible with conventional beam-scanning radars. The SAR generates high-resolution remote sensing image of target objects. A SAR is typically mounted on a moving platform such as an aircraft or spacecraft. One advantage of a SAR is

that image acquisition is possible even at night or during bad weather because a SAR is an active system that uses microwaves.

- **InSAR:** an interferometric synthetic aperture radar is a radar technique used in geodesy and remote sensing. Two or more SAR images are used to generate maps of surface deformation or digital elevation, using differences in the phase of the waves returning to the InSAR platform like a satellite or aircraft. InSAR is applicable for geophysical monitoring of natural hazards, for example earthquakes, volcanic eruptions, and landslides.

6.2 Usage of UAVs in various disaster situations

UAVs can be used for monitoring various types of disasters. The followings are representative cases that UAVs can be used for.

- **Drought:** UAVs with a multispectral/hyperspectral camera can be used to vegetation and land monitoring.
- **Earthquake:** UAVs with a multispectral/hyperspectral camera can be used to detect thermal anomalies prior to earthquakes. UAVs with a LIDAR or an InSAR can be used to assess earthquake damage and to measure surface displacement.
- **Fire:** UAVs with a visible light camera or a thermographic camera can be used to detect and monitor wildfires and urban fires. Wildfire fuel mapping can be performed by UAVs with a hyperspectral camera.
- **Flood:** UAVs with a visible light camera or a multispectral/hyperspectral camera can be used to detect flooded areas.
- **Landslide:** UAVs with a visible light camera or a LIDAR can be used to detect landslide regions. A landslide susceptibility map can be created using LIDAR/InSAR imagery.
- **Volcanic eruption:** UAVs with a thermographic camera can be used to monitor active volcanic areas.

6.3 Basic concept of the Disaster information services using UAVs

Figure 6-1 illustrates the basic conceptual flows of the disaster information services using UAVs. The sensory data are acquired and transferred from UAVs to ground computer servers. The transferred data are processed and analysed for disaster prediction, disaster detection, and disaster response. Finally, the analysed disaster information is delivered to disaster relief systems and early warning systems using the common alerting protocol (CAP) [ITU-T X.1303 bis]. The sensory data acquired by UAVs needs to be transferred in a standard way to server systems which detects, predicts, and response to disaster situation. The disaster information produced by disaster monitoring and analysing system need to be presented and delivered to the disaster warning/response systems in a standard way.

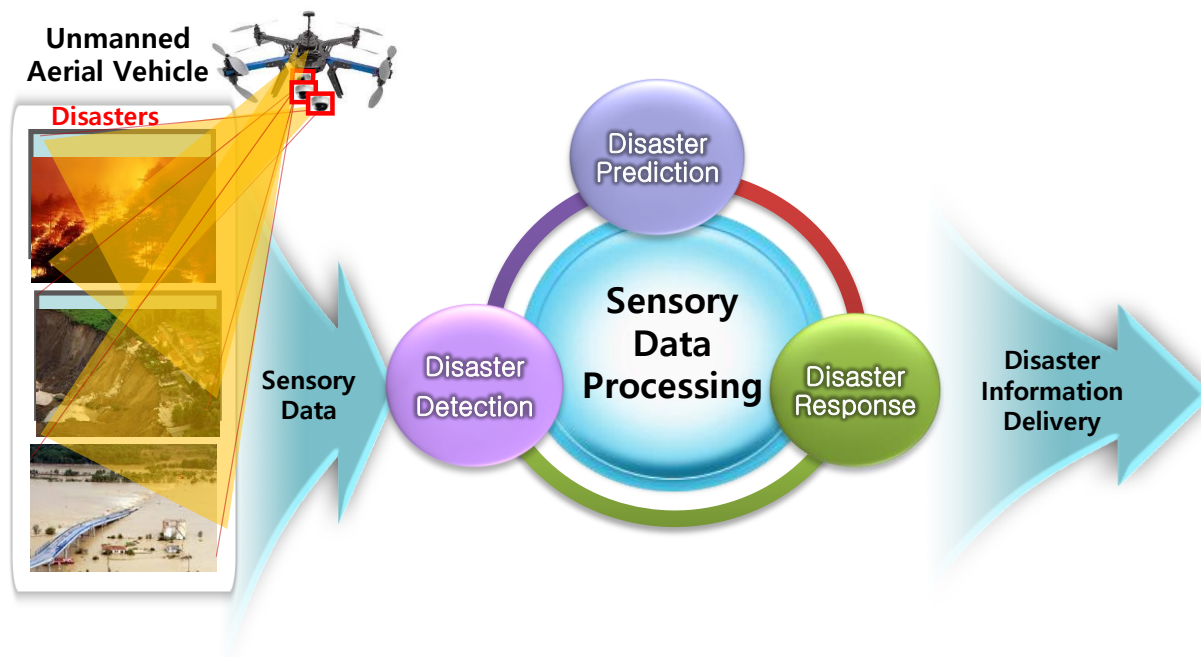


Figure 6-1 – Conceptual flows of the disaster information services using UAVs

7 Use cases and scenarios

The phases of a disaster information services can be categorized as “preparedness”, “response and relief”, and “recovery and reconstruction”. Each phase corresponds to “before disaster”, “during disaster”, and “after disaster” [ITU-T FG-Over]. This clause describes use cases and its scenarios for various representative disaster situations.

7.1 Use cases for drought

7.1.1 Preparedness phase

The disaster information service using UAVs can be used for detection of agricultural drought. Use-cases are described below.

- The risk for an agricultural drought can be predicted from water level measurement of river near farmland with UAV-mounted visible light camera.
- The risk for an agricultural drought can be detected from measurements of soil moisture and vegetative state by a UAV-mounted hyperspectral or multi-spectral camera.
- An UAV equipped with a temperature-humidity sensor can detect differences of the atmospheric state.

Computer vision technologies can be used for automatic detection of agricultural drought stress.

(1) Scenario with on-board drought detection

An on-board computer system of a UAV analyses sensor data and detects droughts in this scenario. This scenario requires considerable on-board computing power and battery capacity.

- A UAV or UAVs patrol designated regions.
- The on-board computer system acquires overlapping aerial images of the regions and analyses sensor data.

- If a drought is detected, the sensor data and related information is sent to a drought incident command centre via wireless communication.

(2) Scenario with land-based drought detection

A ground computing facility analyses sensor data and detects droughts in this scenario. An on-board computer system of a UAV performs limited processing like resampling of the acquired sensor data.

- A UAV or UAVs patrol designated regions.
- The on-board computer system acquires overlapping aerial images of the regions and processes sensor data.
- The processed data is sent to a ground computing facility via wireless communication.
- The ground computing facility analyses the received sensor data.
- If a drought is detected, the sensor data and related information is sent to a drought incident command centre.

7.1.2 Response and relief phase

UAVs can be used for guiding farmland hydration and forecasting droughts in the response and relief phase. Use-cases are described below.

- Still images and live motion pictures from UAVs can be used for guiding farmland hydration.
- Sensor data from UAVs can be used for predicting the area of potential agricultural farmland.
- UAVs carrying speakers can be used for alarming farmer in drought area.

7.1.3 Recovery and reconstruction phase

Images from UAVs can be used for damage assessment.

- Visible photographs, multi-spectral, and hyperspectral data can be used to assess the extent of the damage by droughts and to monitor the recovery of the vegetation in the farmland.
- Reservoir dredging plans in drought-prone areas can be established by using various accumulated climate and drought information collected from UAVs.

7.2 Use cases for earthquake

7.2.1 Preparedness phase

The disaster information service using UAVs can be used for prediction and detection of earthquakes. Use cases are described below.

- It was found that there were unusual increases in land surface temperature called the thermal anomalies before some strong earthquakes. The thermal anomaly happens about 1-24 days before an earthquake, with the temperature increasing by 3-12°C or more and disappears a few days later. Thus, the risk for earthquake can be estimated from measurements of the land surface temperature by a UAV carrying a multispectral camera.
- Damages to man-made structures and topological changes by earthquakes can be detected by a UAV with a visible light camera.

Computer vision technologies can be used for automatic detection of earthquake.

(1) Scenario with on-board earthquake detection

An on-board computer system of a UAV analyses sensor data and detects earthquakes in this scenario. This scenario requires considerable on-board computing power and battery capacity.

- A UAV or UAVs patrol designated regions.

- The on-board computer system acquires overlapping aerial images of the regions and analyses sensor data.
- If an earthquake is detected, the sensor data and related information is sent to an earthquake incident command centre via wireless communication.

(2) Scenario with land-based earthquake detection

A ground computing facility analyses sensor data and detects earthquakes in this scenario. An on-board computer system of a UAV performs limited processing like resampling of the acquired sensor data.

- A UAV or UAVs patrol designated regions.
- The on-board computer system acquires overlapping aerial images of the regions and processes sensor data.
- The processed data is sent to a ground computing facility via wireless communication.
- The ground computing facility analyses the received sensor data.
- If an earthquake is detected, the sensor data and related information is sent to an earthquake incident command centre.

7.2.2 Response and relief phase

UAVs can be used for guiding earthquake response and evacuation in the response and relief phase. Use-cases are described below.

- Still images and live motion pictures from UAVs can be used for guiding earthquake response and evacuation efforts.
- UAVs carrying speakers can be used for alarming people in a danger zone.
- UAVs can deliver relief packages to people.

7.2.3 Recovery and reconstruction phase

Images from UAVs can be used for damage assessment.

- Visible photographs, multispectral photographs, and LIDAR data can be used to assess the extent of the damage and to monitor the recovery of the earthquake area.

7.3 Use cases for fire

7.3.1 Preparedness phase

The disaster information service using UAVs can be used for detection of wildfire and industrial fire. Use-cases are described below.

- The risk for wildland fires can be estimated from measurements of soil moisture and vegetative state by a UAV carrying a hyperspectral camera.
- A UAV equipped with a visible light camera can detect flames and smokes in daylight.
- A UAV with a thermographic camera can be utilized for detection of fire and remaining fire.

Computer vision technologies can be used for automatic detection of fire.

(1) Scenario with on-board fire detection

An on-board computer system of a UAV analyses sensor data and detects fire in this scenario. This scenario requires considerable on-board computing power and battery capacity.

- A UAV or UAVs patrol designated regions.

- The on-board computer system acquires and analyses sensor data.
- If fire is detected, the sensor data and related information is sent to a fire incident command centre via wireless communication.

(2) Scenario with land-based fire detection

A ground computing facility analyses sensor data and detects fire in this scenario. An on-board computer system of a UAV performs limited processing like resampling of the acquired sensor data.

- A UAV or UAVs patrol designated regions.
- The on-board computer system acquires and processes sensor data.
- The processed data is sent to a ground computing facility via wireless communication.
- The ground computing facility analyses the received sensor data.
- If fire is detected, the sensor data and related information is sent to a fire incident command centre.

7.3.2 Response and relief phase

UAVs can be used for guiding firefighting and evacuation in the response and relief phase. Use-cases are described below.

- Still images and live motion pictures from UAVs can be used for guiding firefighting and evacuation efforts.
- Sensor data from UAVs can be used for predicting the evolution of fire.
- UAVs carrying speakers can be used for alarming people in a danger zone.
- UAV can deliver a relief package to people.

7.3.3 Recovery and reconstruction phase

Images from UAVs can be used for damage assessment.

- Visible photographs, infrared photographs, and SAR images can be used to assess the extent of the damage and to monitor the recovery of the vegetation.

7.4 Use cases for flood

7.4.1 Preparedness phase

The disaster information service using UAVs can be used for detection of flooding and an overflowing river. Use-cases are described below.

- The risk for a flood can be estimated from topographic measurement data of flooded areas and cross sections of a river by a UAV carrying a LIDAR sensor.
- The risk for an overflowing river can be estimated from measurements of soil moisture and vegetative state by a UAV carrying a multi-spectral camera.
- A UAV equipped with a visible light camera can detect changes of the surface of an overflowing river in daylight.

Computer vision technologies can be used for automatic detection of floods.

(1) Scenario with on-board flood detection

An on-board computer system of a UAV analyses sensor data and detects floods in this scenario. This scenario requires considerable on-board computing power and battery capacity.

- A UAV or UAVs patrol designated regions.

- The on-board computer system acquires overlapping aerial images of the regions and analyses sensor data.
- If a flood is detected, the sensor data and related information is sent to a flood incident command centre via wireless communication.

(2) Scenario with land-based flood detection

A ground computing facility analyses sensor data and detects floods in this scenario. An on-board computer system of a UAV performs limited processing like resampling of the acquired sensor data.

- A UAV or UAVs patrol designated regions.
- The on-board computer system acquires overlapping aerial images of the regions and processes sensor data.
- The processed data is sent to a ground computing facility via wireless communication.
- The ground computing facility analyses the received sensor data.
- If a flood is detected, the sensor data and related information is sent to a flood incident command centre.

7.4.2 Response and relief phase

UAVs can be used for guiding evacuation and forecasting floods in the response and relief phase. Use-cases are described below.

- Still images and live motion pictures from UAVs can be used for guiding evacuation efforts.
- Sensor data from UAVs can be used for predicting the path of potential flood waters.
- UAVs carrying speakers can be used for alarming people in a danger zone.
- UAV can deliver a relief package to isolated people by an overflowing river or stream.

7.4.3 Recovery and reconstruction phase

Images from UAVs can be used for damage assessment.

- Visible photographs, multi-spectral photographs, and LIDAR data can be used to assess the extent of the damage by floods and to monitor the recovery of the vegetation near a river.

7.5 Use cases for landslide

7.5.1 Preparedness phase

The disaster information service using UAVs can be used for detection of landslides. Use-cases are described below.

- The risk for landslides can be estimated from measurements of displacement rate as well as changes in the surface topography by a UAV carrying a LIDAR sensor.
- The risk for landslides can be estimated from measurements of soil moisture and vegetative state by a UAV carrying a multi-spectral camera.
- A UAV equipped with a visible light camera can detect changes of the surface topography in daylight.
- A UAV with an infrared thermographic camera can be utilized for detection of landslides at night.

Computer vision technologies can be used for automatic detection of landslides.

(1) Scenario with on-board landslide detection

An on-board computer system of a UAV analyses sensor data and detects landslide in this scenario. This scenario requires considerable on-board computing power and battery capacity.

- A UAV or UAVs patrol designated regions.
- The on-board computer system acquires overlapping aerial images of the regions and analyses sensor data.
- If a landslide is detected, the sensor data and related information is sent to a landslide incident command centre via wireless communication.

(2) Scenario with land-based landslide detection

A ground computing facility analyses sensor data and detects landslide in this scenario. An on-board computer system of a UAV performs limited processing like resampling of the acquired sensor data.

- A UAV or UAVs patrol designated regions.
- The on-board computer system acquires overlapping aerial images of the regions and processes sensor data.
- The processed data is sent to a ground computing facility via wireless communication.
- The ground computing facility analyses the received sensor data.
- If a landslide is detected, the sensor data and related information is sent to a landslide incident command centre.

7.5.2 Response and relief phase

UAVs can be used for guiding evacuation in the response and relief phase. Use-cases are described below.

- Still images and live motion pictures from UAVs can be used for guiding evacuation efforts.
- Sensor data from UAVs can be used for predicting the evolution of landslide.
- UAVs carrying speakers can be used for alarming people in a danger zone.
- UAVs can deliver relief packages to people.

7.5.3 Recovery and reconstruction phase

Images from UAVs can be used for damage assessment.

- Visible photographs, infrared photographs, LIDAR or multi-spectral data can be used to assess the extent of the damage by landslides and to monitor the recovery of the vegetation nearby landslide areas.

7.6 Use cases for landslide

7.6.1 Preparedness phase

The disaster information service using UAVs can be used for monitoring volcanic activities without exposing personnel to volcanic hazards. Volcanic tremor, ground deformation, thermal anomalies, and gas emissions are considered as indicators of forecasting volcanic activity. Use-cases are described below.

- UAVs carrying thermal cameras can obtain both overall view of the behaviour of an active volcano and local precise information.
- LIDAR or InSAR mounted on a UAV can be used for monitoring ground deformation.

- Thermal anomalies can be detected by UAVs carrying thermal cameras.
- A UAV with chemical sensors can be used for analysing volcanic gas.

Signal processing technologies can be used for analysis of volcanic activities.

(1) Scenario with on-board volcanic eruption detection

An on-board computer system of a UAV analyses sensor data and detects volcanic eruption in this scenario. This scenario requires considerable on-board computing power and battery capacity.

- A UAV or UAVs patrol designated regions.
- The on-board computer system acquires sensor data of the regions and analyses acquired data from payload mounted on an UAV.
- If a volcanic eruption is detected or predicted, the sensor data and related information is sent to a volcano incident command centre via wireless communication.

(2) Scenario with land-based volcanic eruption detection

A ground computing facility analyses sensor data and detects volcanic eruption in this scenario. An on-board computer system of a UAV performs limited processing like resampling of the acquired sensor data.

- A UAV or UAVs patrol designated regions.
- The on-board computer system acquires sensor data of the regions and processes sensor data.
- The processed data is sent to a ground computing facility via wireless communication.
- The ground computing facility analyses the received sensor data.
- If a volcanic eruption is detected or predicted, the sensor data and related information is sent to a volcano incident command centre.

7.6.2 Response and relief phase

UAVs can be used for guiding volcanic eruption response and forecasting volcanic activities in the response and relief phase. Use-cases are described below.

- Still images and live motion pictures from UAVs can be used for guiding volcanic eruption response and forecasting volcanic activities.
- Sensor data from UAVs can be used for predicting the behaviour of active volcanoes and evaluation of the associated hazards.
- UAVs carrying speakers can be used for alarming people living in active volcanoes areas.

7.6.3 Recovery and reconstruction phase

Images from UAVs can be used for damage assessment.

- Visible photographs, high spatial and spectral resolution sensor data can be used to assess the extent of the damage and to monitor the recovery of the damaged area.

7.7 Use cases for tsunami

7.7.1 Preparedness phase

The disaster information service using UAVs can be used for detection of tsunami. Use cases are described below.

- It was found that there were variations in sea surface before some strong tsunamis. An approaching tsunami exhibits general appearances as a sudden fast rising tide, a subsequent

withdrawal of coastal ocean seawater, a cresting wave of steep and almost vertical slope of several metres height. Thus, the risk for tsunami can be estimated from measurements of the sea surface variation by a UAV carrying a high frequency (HF) radar.

- Before the approaching tsunami strikes, high-speed infrasonic waves induced by tsunami can be detected by a UAV with an infrasonic sensor.

Signal processing technologies can be used for automatic detection of tsunami.

(1) Scenario with on-board tsunami detection

An on-board computer system of a UAV analyses sensor data and detects tsunami in this scenario. This scenario requires considerable on-board computing power and battery capacity.

- A UAV or UAVs patrol designated regions.
- The on-board computer system acquires sensor data of the regions and analyses sensor data.
- If a tsunami is detected, the sensor data and related information is sent to a tsunami incident command centre via wireless communication.

(2) Scenario with land-based tsunami detection

A ground computing facility analyses sensor data and detects tsunami in this scenario. An on-board computer system of a UAV performs limited processing like resampling of the acquired sensor data.

- A UAV or UAVs patrol designated regions.
- The on-board computer system acquires sensor data of the regions and processes sensor data.
- The processed data is sent to a ground computing facility via wireless communication.
- The ground computing facility analyses the received sensor data.
- If a tsunami is detected, the sensor data and related information is sent to a tsunami incident command centre.

7.7.2 Response and relief phase

UAVs can be used for guiding tsunami response and evacuation in the response and relief phase. Use-cases are described below.

- Still images and live motion pictures from UAVs can be used for guiding tsunami response and evacuation efforts.
- UAVs carrying speakers can be used for alarming people in a danger zone.
- UAVs can deliver relief packages to people.

7.7.3 Recovery and reconstruction phase

Images from UAVs can be used for damage assessment.

Visible photographs and LIDAR data can be used to assess the extent of the damage and to monitor the recovery of the tsunami-hit area.