HADMÉRNÖK

VIII. Évfolyam 3. szám - 2013. szeptember

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EXPLORING THE CAPACITIES OF AIRBORNE TECHNOLOGY FOR THE DISASTER ASSESSMENT

Abstract

This article reviews the existing airborne technologies and explores their capacities for the disaster assessment.
The first part of this article aims at providing comprehensive information about disaster assessment and the existing airborne technology. First, some definitions and general introductory information are given about disaster and airborne technology. It is followed by an inventory about the different types of disasters, the associated relevant information to be gathered for the situation assessment, and last by a review of the airborne technology (different platforms, sensors and associated capacities).
The second half of this article aims at assessing the capacities of airborne techniques for disaster assessment putting into relation a type of disaster with a method on how to perform the assessment work. This part is completed by the presentation of a set of strategically chosen case studies in order to cover diverse types of disasters and the aerial reconnaissance solutions employed.

A cikk bemutatja a katasztrófa helyzetértékelésben alkalmazható légi felderítő eljárások lehetőségeinek áttekitését. A közlemény első felében jellemzésre kerülnek a katasztrófa típusok, valamint a helyzetértékeléshez szükséges információk. A publikáció második részében a légi felderítésben használt módszerek és alkalmazhatóságuk kerül elemzésre illetve az egyes légi felderítő eljárások hatékonyságának bemutatása gyakorlati példák segítségével.

Keywords: *airborne, reconnaissance, disaster, catastrophe, remote sensing, sensors ~ légierő, felderítés katasztrófa, távérzékelés, érzékelők*

INTRODUCTION

An airborne disaster *assessment* is a preliminary survey made by airborne means in order to collect information about the situation on an area affected by a disaster. Information collect can be oriented towards several goals at the same time, for example the estimation of the damages done, or easing the orientation of the first emergency responses (first help to people), or supporting situation analysis for protective measures (in case of a dynamic disaster which can endanger a larger area).

This study considers all existing types of disasters which are commonly divided in two groups: natural (meteorological, hydrological, biological, etc.) and man-made (sociological and technological hazards).

Airborne techniques are usually chosen for their ability to cover large areas within a short time. Airborne remote sensing also offers some advantage compared to field survey in case a road network infrastructure is not usable or if the level of contamination on the ground is unknown or could threaten health.

The evolution of sensors and processing capabilities has widened the spectrum of applications where aerial reconnaissance can be utilized. Classical imagery has been completed with a couple of new technologies like LiDAR, hyperpectral imagery, thermal imagery which already has or could find some applications in disaster management. The recent trend with the use of UAV platform and UAV sensor technology is also considered in this study.

DISASTER TYPOLOGY AND RELEVANT SITUATION INFORMATION TO COLLECT

This part takes as an input the different types of disasters and provides an inventory of the information potentially relevant in the different assessment processes. Generally three types of assessment are used:

Situation (Disaster) Assessment. This assessment gathers information on the magnitude of the disaster and the extent of its impact on the population and the physical infrastructure, as well as the environment.

*Needs Assessment***.** The initial needs assessment identifies resources and services for immediate emergency measures to save and sustain the lives and livelihoods of the affected population. Conduct this assessment at the site of a disaster or at the location(s) of displaced population(s).

Environmental Impact Assessment. The need to consider environmental issues during disaster operations rests on four considerations:

- Environmental degradation often causes natural disasters and aggravates their effects.
- Competition over natural resources frequently provokes armed conflicts.
- Disasters can result in significant environmental damage.
- Relief assistance can result in negative environmental impacts, leading to a need for additional assistance to solve problems that could have been avoided or at least mitigated if they had been anticipated in the disaster response planning stages.

The airborne assessment is very important in the situation and environment impact assessment.

The different types of disaster are listed in tab.1. Disasters can be divided in two groups: natural disaster and man-made disasters. The first column of tab.1. summarizes the information gathered from different sources dealing with disaster classifications. [1], [2], [3] The table was filled considering a disaster and information potentially available from aerial means which could be relevant to disaster management. For all the types of disaster it is relevant to know:

– the extent of the impacted area
– the intensity of the damages
– if there are difference with the intensity of damaged inside an impacted area (zonation)
– if there are other areas are potentially endangered
– the location of the victims for their assistance.

As this information is common for all the disasters, to avoid repetition, they are not written in tab.1.

Type of disaster	Relevant information to be gathered by aerial reconnaissance means
Natural disasters	
Geophysical	
Earthquakes	* Damage to infrastructure and critical facilities * Damage to homes and commercial buildings.
Tsunami	***Number of people to evacuate. * Damage to infrastructure and critical facilities * Damage to homes and commercial buildings. *Distinguishing the areas that dried for first help.
Volcanic eruption	*** Number of people to evacuate. **Detection of active areas though the thermal activity, gas emission or through the changes in elevation. **Gathering information about speed and direction of the lava, lahars, etc flows as well as terrain elevation, POI on the trajectory.
Mass movement (avalanche, land slide, rock fall)	***Existence of unstable snow layer, rocks, soil layer. */**Direction of the movement. Speed. POI on the trajectory. *Info about critical infrastructure status
Hydrological	
Floods	*** Number of people to evacuate. **Volumetric data. */**/***Elevation data. Precise surface model. **Evolution of the situation
Mass movement (land slide, rock fall)	*** Number of people to evacuate. ***Existence of unstable snow layer, rocks, soil layer. */**Direction of the movement. Speed. POI on the trajectory. *Info about critical infrastructure status
Meteorological	*Short term small scale*
Blizzards	*Info about road network obstruction
Storms/Cyclone	*** Number of people to evacuate. *Info about critical infrastructure status (bridges, main roads, hospital, etc.)
Climatological	*Medium to long term, large scale*
Wildfires	*** Number of people to evacuate. **Hot spots detection. **Live evolution of the situation (direction of the fire).
Droughts	
Extreme temperature	
Biological	**Spread of diseases in vegetation, spread of invasive species, blooms (algae).
Extraterrestrial	
Human-made disasters	
Sociological	
Civil disorder, terrorism and war	Impacted area, impacted infrastructure, victims, intensity of damages. Refer to fire, industrial, nuclear, CBRN.
Technological	
Industrial	*Location, thickness, concentration of contamination.
Fire	**/*Localization of hot spots. **Information about efficiency of firefight (for adapting the fight).
Transportation	*chemical identification *identification of POI/AOI to protect (water catchments, rivers, etc)
Nuclear	*chemical identification *dose rate quantification *concentration and dissemination.
CBRN	**chemical identification **quantification (concentration, spread, dissemination) of CBRN agent. **identification of POI/AOI to protect (water catchments, rivers, etc)

1. table. Relevant information to be collected by aerial means for each type of disaster *post-,**during, ***pre-disaster.

Depending on the type of disaster assessment activities can be oriented on the pre-disaster phase (when disaster protection is possible), during the disaster (if conditions are favorable for flying), and post-disaster phase (first help guidance). Almost all the types of disaster listed found some potential application of aerial reconnaissance. Some disasters like CBRN, nuclear, industrial requires the collect of measurable physical values (concentration, dose rate, etc) whereas other disaster rather requires environmental and geographical characteristics (flooding) and a third category rather requires infrastructure status information (cyclone, earthquake).

This part has answered to the question "which information should be gathered". The next question to be logically answered is "how to gather the information?"

OVERVIEW OF THE TECHNICAL CAPACITIES OF AIRBORNE TECHNOLOGY

This part introduces and categorizes the different types of sensors and their detection and implementation capacities.

Different platform for very different aims and operational context

Airborne reconnaissance employs different types of platforms with different associated capacities. Tab. 2 summarizes the main advantages and disadvantages between the different platforms. Aircraft reconnaissance is privileged to cover large areas within short time at relatively high altitude. Helicopters are utilized when flight characteristics require low altitude, low speed or following a corridor trajectory. UAV are limited to the survey of small areas; their main limitation is the carriage load.

Platform	Advantage	Disadvantage
Aircraft	Faster flight speed and higher altitude allow larger area coverage per unit of time.	Cannot perform acquisition at low speed. Can not follow curves and corridors. Minimal AAG required for safety.
Helicopter	No minimal speed. Possibility to fly at low AAG[1] and to follow terrain elevation. Possibility to fly curves and corridors.	The most costly. Lower coverage capacity per unit of time.
small UAV	Flexibility, maneuverability. Adapted to small areas. The less costly.	Limitation with the carriage load. Limitation with the coverage capacity. Technology still under development for certain censors.

2. table. Advantages and disadvantages associated to different types of holding platforms

To be noticed platform and sensors cannot be chosen independently. Sensor influences the selection of a platform by its requirements regarding the AAG it should be operated at (which mainly depends on the required accuracy) and the requirement regarding the flight characteristics (ground speed). The nature and size of the target object of the reconnaissance also influence the selection of the platform.

Sensors presentation

Each sensor is characterized by the physical detection principle it is based on (wavelength reflection, absorption, measurement of light travelling time, etc), its capacities (accuracy, detection range, field of view, etc) and the characteristics of the product for the end user. The following paragraphs provide detailed information about a couple of very common sensors used in disaster surveys. Thus completion about aerial sensors is given into a synthetic table (tab.3.).

[1] Altitude Above Ground

Aerial imaging

Nowadays aerial imaging is performed with digital cameras (medium, large and ultra large format). [8], [9] Red, Green, Blue and Near Infra Red channels (RGBN) are the most commonly used. GSD[2] is governed by the flight altitude (AAG). The smaller the GSD is, the most detailed the pictures are. From a given GSD the required AAG is calculated. Based on the AAG, the FOV of the sensor (determined by the pixel size and number of pixel of the CDD array) and the requirement for the overlay between the frames it possible to determine the position of the flights lines, the frame footprints and to calculate the flight time (tab.7. provide a good example). Maximal flight speed is determined by the maximal frame rate of the sensor (1 frame per second in the case of Leica RCD30 camera for example). All these operations are done and assisted by flight planning software. Camera control system is coupled with GPS/IMU system to store the external orientation parameters which are used during the post-processing of the images for their geometric correction and correct positioning into a block (photogrammetry). Aerial imaging is the most versatile reconnaissance mean for mapping the status over an area. In term of time, 5h roughly covers 260 km^2 with a medium format camera at 1200m AAG. Post processing overall requires 24 to 30h to make the radiometric image enhancement, to calculate trajectories, to determine image external orientation and to mosaic images. As a general rule an ortho-image product can be available within 24-72h after the beginning of mobilization of the aircraft (depending on the size of the AOI and final accuracy required). Oblique imagery

Imagery is useful in the entire situation where photo interpretation provides relevant information about the situation (status of roads, buildings, areas flooded or not, impacted or not, etc).

Aerial laser scanning

LiDAR is the modern mean to establish terrain models (DTM) and surface models (DSM). The sensor measures the travelling time between the source point and the ground and derivate a distance between the sensor and the target. Laser scanner is operated coupled with a GPS/IMU system. The orientation of the laser beam is known every time a shot is sent. Knowing the position of the aircraft and the orientation and the beam, each point hit on the ground can be positioned in a x,y,z digital model. The main characteristic of the LiDAR system are the pulse rate (partly determine point density) and the scanning pattern. The overlay between the strip, the flight speed, flight AAG and the pulse rate determine the average point density of the final product. Hydrologic model requires 5 pt/m^2 average densities. The systems can produce clouds of point from 0,5 pt/m^2 to 42 pt/m^2 in general condition of use. Scanning patterns influence the point repartition on the ground (raster, sinusoid, triangular) and at the NADIR in particular. The flight speed is similar to the one for imaging.

DSM and DTM derivates from the cloud of points (after geometric correction, error correction and classification). They can be used for 3D modeling (infrastructure), flood modeling, volumetric calculation, and also in combination with other data (data fusion) for automatic classification (the elevation is a useful input in object oriented classification). [4]

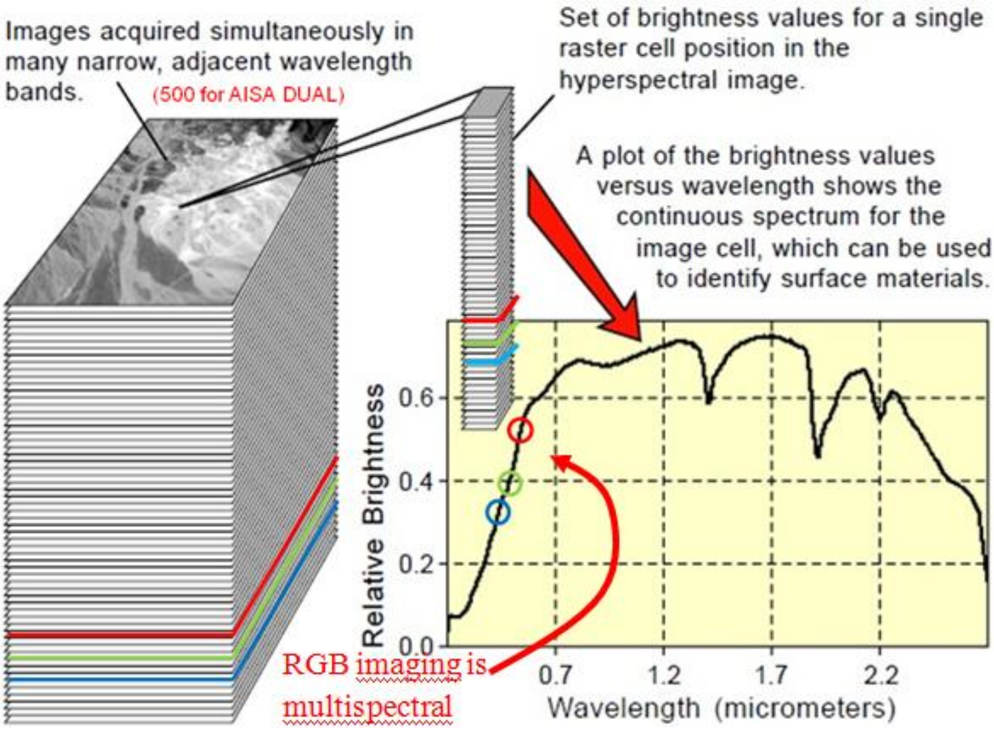
Another application of laser scanning exists, it is called differential laser scanning and it is based on the measurement of the absorbance of the laser beam by the target at variable emission wavelength. [5] The technique is relevant to measure gas concentration in the air, chemical and contamination in the atmosphere. [6], [7]

[2] Ground sampling distance

Hyperspectral imaging

Hyperspectral imaging extends the capacities of imaging with providing spectral data about ground surface objects (different from multi spectral imaging where data is provided for a limited number of and non contiguous spectral values). Hyperspectral spectrometer exists in the VNIR, SWIR, LWIR and FIR regions. Technically they are characterized with their spectral resolution, spectral range and spatial accuracy.

Thematic maps are the products associated to hyperspectral imaging. The huge amount of information from the spectral data about objects on the ground can be derivate to classify the images with higher accuracy. Thus it is possible to classify objects that other methods do not "see" or to make more sharp distinctions. Recent application of hyperspectral imaging was done for oil mapping, contamination mapping, and gas detection in the atmosphere.



1. figure. General principle of hyperspectral imaging and differentiation from multi spectral imaging (RGB)

Aerial spectrometers with more accurate spectral resolution covering several spectral regions are under development (at present they only cover a really narrow part of one spectral region), this will open the era of ultra spectral imaging and they are expected to push forward the limits with air composition detection. [8], [9]

Sensor	Physical detection principle	Capacities	End product
RGBN. Medium, large and ultra-large format digital camera [10], [11]	Measurement of light reflectance by physical objects on the ground at 3+ different wavelength at “NADIR”	Medium format camera (RCD30): 47 km^2/h at 1300m AAG, FOV 60°, 12cm GSD, 51 m/s. Large format camera (ASD80): 170 km^2/h with 15 cm GSD, 65m/s.	RGBN ortho-images, mosaics.
RGB oblique imagery [12], [13]	5 RGB cameras are disposed at 45° in forward backward, right and left directions + NADIR	10-50 cm GSD. Similar to medium format camera.	true-ortho, 2,5D city models. Measurement in enhanced 2,5D view. View around buildings.
Laser scanner (LiDAR) [14], [15]	Active. Distance sensor-target by light travelling time + orientation of the laser beam.	Max. 5cm vertical accuracy, 0-75 degree FOV. 250 kHz. 1-42 point/m^2. First pulse, last pulse, full wave form. Average coverage 50 km^2/h.	Elevation models (DSM, DTM).
Differential absorption LiDAR (DIAL) [6], [7]	Active. Absorption of lights energy by particles or gas in the atmosphere	Water vapor, CO2, aerosol, ozone and gas detection with concentration estimation.	Air composition and element concentration maps.
Hyperspectral imaging	Measurement of light reflectance by physical object of the ground, atmospheric gas at more than 400 wavelengths.	AISA Dual (400-2500 nm (VNIR&SWIR)): 3,3-12nm spectral resolution. 65 cm GSD at 1000m AAG, FOV 24° [16] AVIRIS: 224 contiguous bands for AVIRIS from 400 to 2500 nm [17].	ortho images. Classified images, thematic maps.
Thermal imaging	Measurement of heat emission (and reflection).	Digitherm system: 0,05K thermal resolution for the sensor = +/-1,5K for temp. measurement. [18]	Maps of thermal radiance.
Gamma spectrometry [19], [20], [21], [22]	Gamma photon captured by ionization chamber or by crystals.	Require helicopter at 70km/h, altitude 100m. GM tube, Nai(TI) crystal. Coverage 18-20 km^2/h. Dose rate over 2-5 mGy/h. Count rate over 10-20 μGy/h.	Maps of dose rate at 1m for extended contamination. Localisation of ponctual sources and count rate maps.
Air sampling method [23]	capture of particles in the atmosphere	Volume filtered per unit of time, threshold of concentration detected.	Qualitative and quantitative information about air composition, punctual measurement or average value on a transect.

3. table. Summary about the sensors, detection principle, main capacities and end product

Disaster	Information	Technology and/or product
Earthquake	Building status (standing, collapsed, unstable) Road network status Research of survival	Oblique imagery. Classical RGB imagery. Thermal.
Tsunami	Building status (standing, collapsed, unstable) Road network status Research of survival Area dried ready for first response	Oblique imagery. Imagery, video. Thermal. Imagery, video.
Volcanic eruption	Detection of person to evacuate. Detection of active areas though the thermal activity, gas emission or through the changes in elevation. Gathering information about speed and direction of the lava, lahars, etc flows as well as terrain elevation, POI on the trajectory.	Imaging Thermal imaging, DIAL, LiDAR Imaging, LiDAR.
Avalanches	Location of buried persons. Zonation of impacted area. Zonation of infrastructure impacted. Endangered areas or persons, existence of unstable snow layer.	Thermal imaging (if victim close to surface). LiDAR, RGB imaging. LiDAR.
Floods	Impacted area. Volumetric data. Elevation data. Modeling	Ortho-images LiDAR (DSM, DTM)
Wildfires	Hot spots localization. Firefight efficiency assessment and guidance Change in fire direction, evolution of the situation	Thermal imaging Thermal imaging Thermal and imaging
Blizzards	Impacted infrastructure (road network to be cleaned).	RGB imaging or LiDAR
Cyclonic storms	Detection of person to evacuate. Building status (standing, collapsed, unstable) Road network status Research of survival	RGB imagery or thermal imaging Oblique imagery. Classical RGB imagery. Thermal.
Hailstorm	Impacted area. Impacted infrastructure. Intensity of damages.	RGB imagery
Heat waves	Temperature on the ground.	Thermal imaging.
Health disaster	Spread of diseases in vegetation, spread of invasive species, blooms (algae).	Hyperspectral (vegetation, algae).
Space disasters	Extent of impact Spread of radioactive substance Spread of toxic substance	RGB imaging. Aerial gamma spectrometry Hyperspectral
Civil disorder, terrorism and war	Impacted area, impacted infrastructure, victims, intensity of damages. Refer to fire, industrial, nuclear, CBRN.	Oblique imagery.
Industrial	Information about the localization, concentration of the contamination	Hyperspectral* Hyperspectral*, DIAL*. Hyperspectral* LiDAR (for elevation model in case of flooding risk).
Fire	Localization of hot spots, firefight work assistance	Thermal imaging.
Transportation	Pollution extent (oil spill, water contamination, air contamination)	LiDAR (for elevation data in case of flooding risk). Hyperspectral.
Nuclear	Intensity of contamination, type, location	Aerial gamma spectrometry.
CBRN	Type of contamination, extent.	DIAL [18] Hyperspectral imaging Air sampling.

4. table. with full relation catastrophe, information, technology/measurement method

CONSIDERING TIME OVER THE FULL WORK FLOW FOR THE ASSESSMENT OF AIRBORNE CAPACITIES

The previous part put into relation a type of disaster, the information relevant for its management and the associated airborne technology to mobilize to gather this information. Adequate information and appropriated means for the collection is not sufficient as regards to the catastrophe management situation. The second priority is the management of the time. As only a final product can be exploited in the management of disaster (3D model for LiDAR, thematic maps and ortho-photos for imagery) all the work flow (and associated cumulated time) leading to the delivery of the final product should be considered[3].

The following part introduces the workflow and all the aspects influencing time in an ortho-image production process. The choice is oriented towards ortho-imagery production as it is the most common and versatile reconnaissance product.

GSD depends on AAG

In the aerial data acquisition process, first a decision is made regarding the area to be flown. Secondly the project manager has to make a choice as regards to the quality of the data which in imagery means the size of pixels on the ground (GSD or spatial resolution). The GSD is governed by fixed sensors characteristics (FOV (related to the optics), number of pixels on the CCD array, size of the pixels) and the altitude of flight (the only adaptable entry).

AAG and FOV determine strip width which affects the flight time

Once AAG is fixed it is possible to position the flight lines over the AOI, making additional decision about the required overlay between frame footprints. The number of flight lines conditions the total flight time. All this work is assisted by software and a digital flight plan is issued at the end of this process.

In practice, and in particular in the case of disaster reconnaissance, rush data are targeted which result in a lower spatial resolution but favor production time with higher AAG.

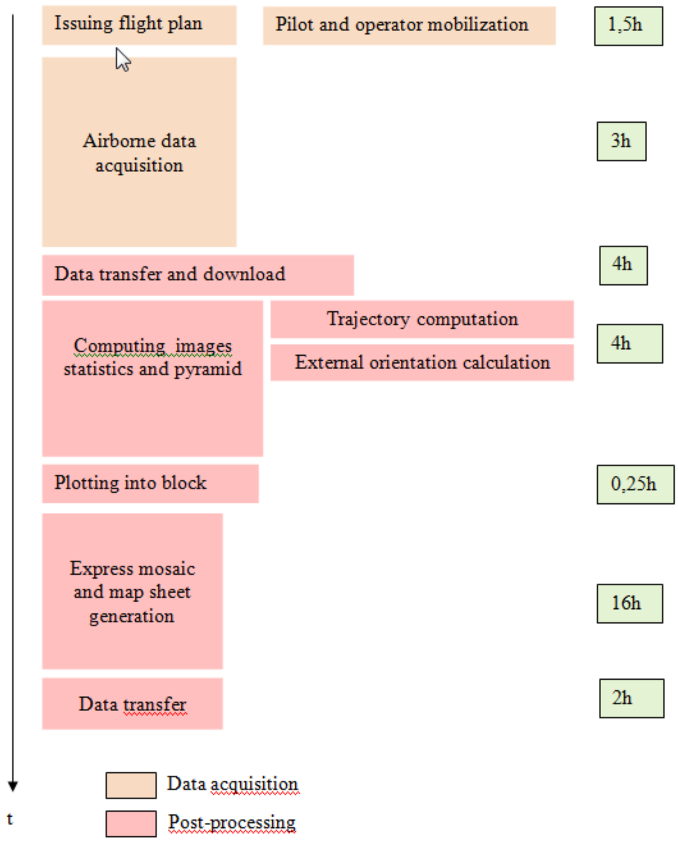
AAG affects file size which affects post-processing time.

The number of frames made over an area depends on the AAG and the associated number of flight lines. The size of the data is proportional to the number of frame for the image and to the time of flight for the trajectory data. The time of post-processing is directly related to the size of the dataset.

General ortho-image production workflow and timeline

The following scenario corresponds to the production of an express mosaic for the 776 frames of the Zala AOI presented in fig.2. The complete ortho-rectification with automatic point matching, bundle adjustments and the use of corrected DSM for ortho-rectification would require much more time. From the project planning to the delivery of the product a minimum time of 30h is required.

[3] The data generated by the sensor is usually in a raw format and it is not classified nor geocorrected, so it is not exploitable.



Advisory to produce table for each sensors or combination of sensors about operating time, spatial accuracy and post-processing time.

New solution that allow following the disaster in real time and mapping the POI on touch screen during the flight. [24] Those solutions are efficient for small areas.

SELECTION OF RELEVANT CASE STUDIES

The part aims at providing concrete and developed examples about the use of aerial reconnaissance means for a diverse selection of disasters.

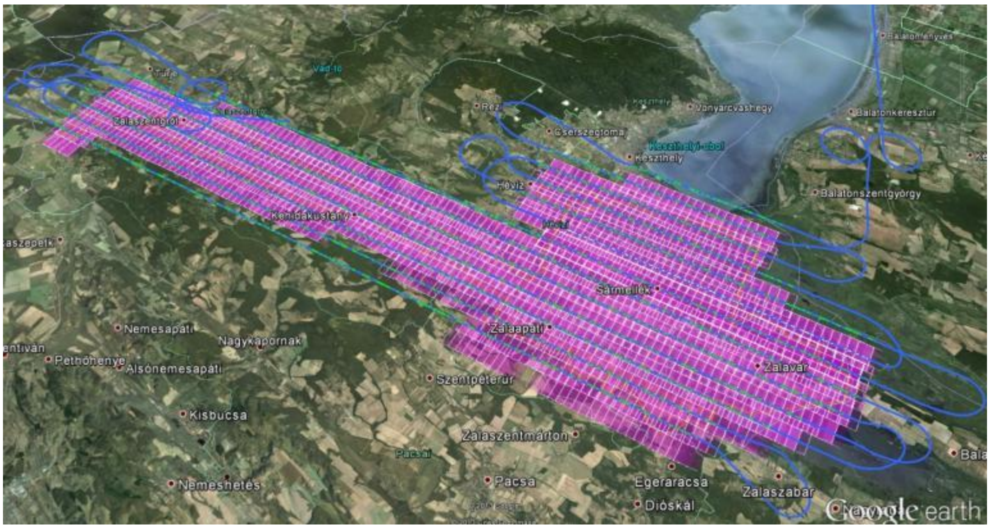
RGB imagery and LiDAR data for flooding reconnaissance (natural disaster)

This case study aims first at introducing aerial imagery, the reconnaissance mean the most versatile and the most generally used. Our second belief is to present information about flooding, a natural disaster that frequently happens. Because of its geophysical characteristic (flat land, rivers draining much extended surface abroad) Hungary is particularly exposed to flooding. Our team performed two aerial reconnaissance surveys on April the 16th over Zala and Kapos rivers right after the flooding event. The data acquisition was performed with a Cesna C-206 aircraft equipped with a Leica dual system for ortho-imagery and LiDAR (RCD30 medium format camera and ALS70 laser scanner). RGBN ortho-imagery with 15cm GSD was produced in combination with a 4-5 pt/m^2 density cloud of points.

Number of flight lines	32	Average point density at NADIR	4 pt/m^2
AOI total area	270 km^2	Expected vertical accuracy (LIDAR)	0,09 m
Length of flight	820 km	Expected accuracy (Ortho)	15 cm
Taxi time from base to AOI	0,25 h	Max flight altitude above ground	1300 m
Time to fly	5,7 h	FOV	54°
Number of frame	1833	Overlay between footprint	30%
Ortho GSD	15 cm	strip width	1325 m
Average point density	5 pt/m^2	Flight speed	185 km/h

5. table. Main characteristics of the flight for Zala and Kapos AIO

Fig.2. show the flight report over the Zala AOI. The airplane trajectory is represented with a blue line. The footprint of each frame is figured with a purple square. A total of 776 frames were taken in 3 hour (including taxi).



2. figure. Flight report over the Zala AOI

Fig. 3 shows a sample of territory affected by the flooding. Flooded areas can easily be identified visually on the picture (a) and (b). With the use of a dual system, the visual interpretation and digitalization of flooded areas can be replaced by an automatic classification using the low reflectance of laser beam by the water. This fusion is of high interest for the production of rush data on the extent of flood area. Additionally LiDAR elevation data is used as an input for hydrological model.

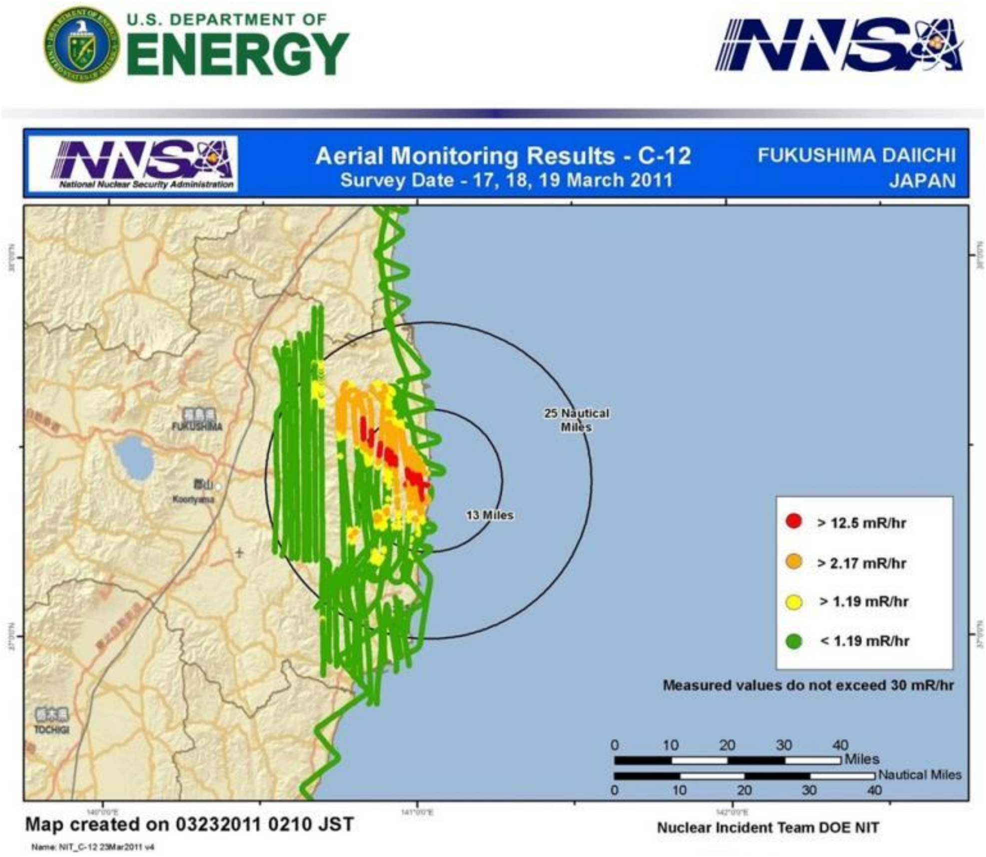
3. figure. Ortho image over a flooded area

Almost immediate gamma reconnaissance over an extended area after the Fukushima disaster (March 11, 2011)

With one nuclear power plant in Páks, several ones in the neighbor countries (a) and radiologic materials with long range travel capacities in the case of a serious accident, nuclear risk should be considered and associated reconnaissance capacities developed[4]. The catastrophe of Fukushima demonstrated how important the airborne capacity is.

On March 14, 2011 the US department of Energy (DOE) deployed a tailored Management Response Team (CMTR) and Arial Measuring System (AMS) capability using military airlift to Yokota Air Base. By March 17, the AMS had acquired a general picture of the level of contamination on the ground. [25] The flight operations were curtailed on March 22-23 due to weather conditions. On March 25, 2011the first radiological assessment report was issued.

The radiation data was collected with a fixed-wing aircraft (C-12), with an array of large thallium activated sodium iodide (NaI(T)) crystals and associated readout electronics to produce time and location referenced measurements. AMS data represented as exposure rate 1 meter from the ground at the time the measurement occurred. [26], [27] The map issued helped to affine the contour of the most impacted area, to guide the protection measures and to guide the next surveys for the monitoring of the radiological assessment.



4. figure. A map from March 25, 2011 report

The approach provided precise results within a short time over an extended area (mobilization on the 14th, and first results on the 17th). The delay which might be caused by the weather condition is an important point to consider for all the aerial survey.

[4] Hungarian defense force has equipped a helicopter with an aerial reconnaissance system (LABV)

Complementary use of multiple sensing aerial capacities on the red mud disaster (industrial disaster, October 4, 2010)

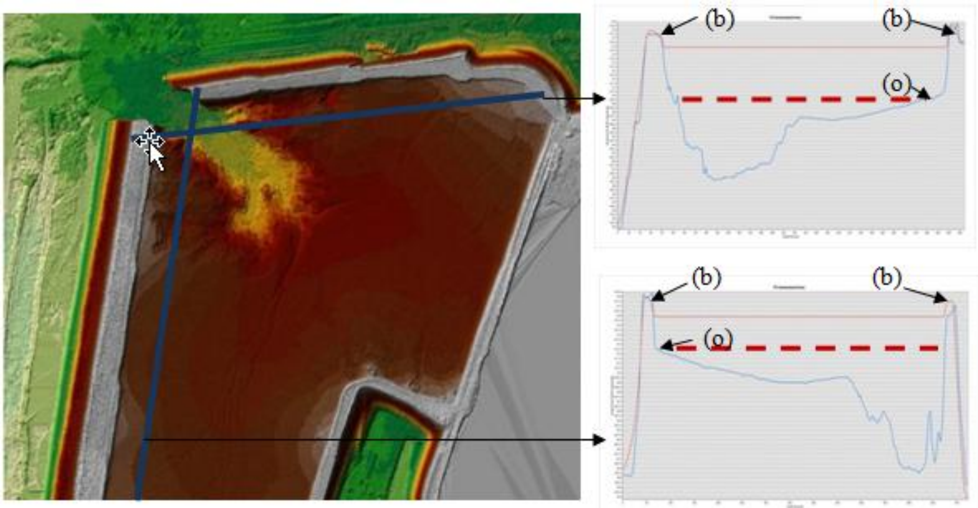
On October 2010, the embankments of an industrial reservoir located in Kolontár, Hungary failed and released a mixture of 1.1 million cubic meters of bi-product red sludge which flooded the settlements of Kolontár, Devecser and Somlóvásárhely. An interdisciplinary approach was necessary to tackle all the challenges lain by this totally unexpected event. Five different remote sensing systems were used. [28] Three of them are detailed below.

Aerial LiDAR survey was performed with a Leica ALS60 at 800m AGL in order to issue a final model with 4 pt/m^2 with a vertical accuracy of 10 cm. The objective of the survey was threefold:

- Collecting elevation data as input for hydrological modeling of the flooding,
- Collecting data for the 3D modeling of the reservoir
- Estimating the spilled volume (fig.5).

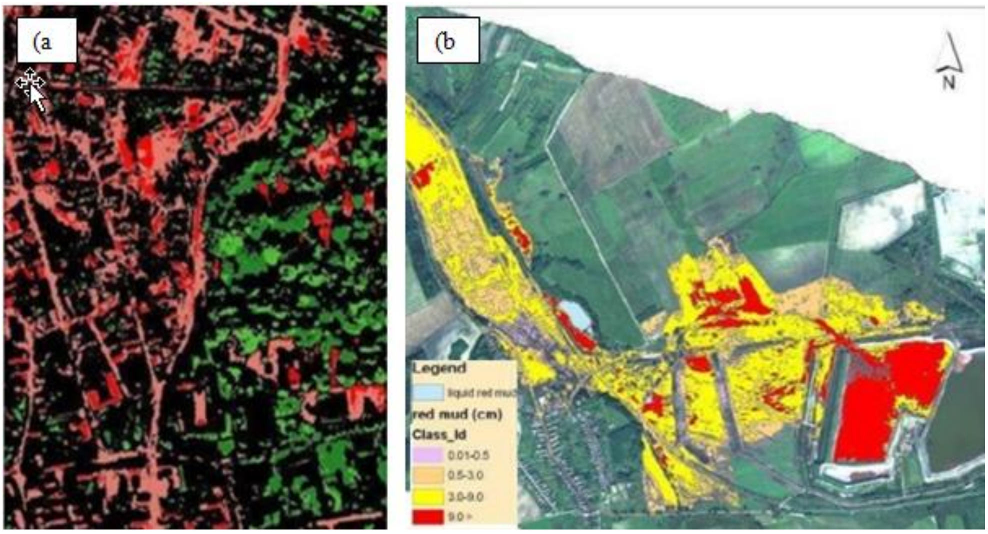
The calculation of the missing volume in the reservoir was done using LiDAR data in combination with stereoscopic measurement with aerial photography pairs. [28]

Fig.5. shows a 3D model (top view) and cross-sections where elevation data was plotted and analyzed. On the two graphs corresponding to the cross-sections, the borders (b) of the dam can easily be identified. The original level of decanted red mud originally stored in the reservoir can be estimated (o), last the level of red mud not decanted (red curve) was plotted. By issuing two DTM (before and after event) and calculating the volumic different it was possible to calculate the missing volume in the reservoir. Calculations gave a total volume of leaking approaching the 1,1 million of cube meters.



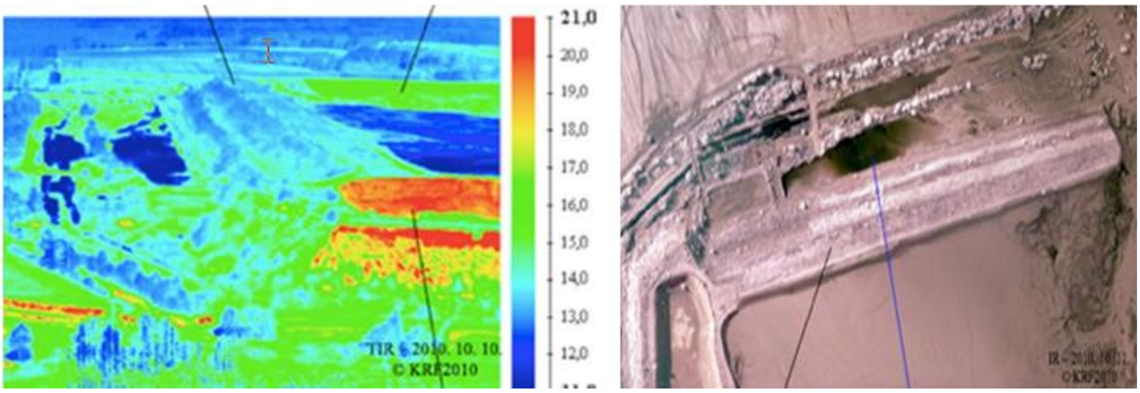
5. figure. 3D model of the reservoir from LiDAR data post-processing and profile lines for estimating the leaked volume

Hyperspectral flight was performed with an AISA Eagle imaging system at 1655m AGL with a corresponding GSD of 1,1m. 253 bands were collected in the 400-970nm region. After geometrical and radiometrical correction and pixel classification, the maps bellow were issued (fig.6.). [29] Those maps were used to guide and prioritize the cleanup work.



6. figure. Thematic maps about contamination zonation
(a) and red mud pollution thickness (b) from hyperspectral imaging

Thermal imaging (NIR, FIR) was applied in order to track invisible breaks and breach in the banks of the dam. Wet leaking areas were identified in the shot near the reservoir (fig.7.). Those clues allude to hidden cracks and leaks. The detailed examination of the whole dam was an important issue for the security of the post-damage work and ground work examinations. The thermal measurements made over a period of seven days allow determining which parts were intact and can be used for moving or could be approached safely. [30]



7. figure. Thermal images (FIR and IR) showing leaks and humid patches

Conclusion

The diverse aerial reconnaissance done on the red mud disaster demonstrated how rich and diverse the field of application of aerial surveying technology can be. Two facts are very important to mention. First, it demonstrated the advantage to use different sensors to provide complementary information on different thematic areas related to the same disaster (status of the dams: detection of hidden cracks, detection of water infiltration, calculation of the volume of the leak; environmental status: extent of the flooded area, thickness of the red sludge layer, wetness status). As a second important fact - considering this event was unique in the history and the research teams who carried out the reconnaissance had neither prepared nor methods ready beforehand - they demonstrated they were able to adapt quickly and produce within a short time new methods for the use of the technology and to produce adequate rush data. This also shows that the technologies are flexible enough to measure phenomena in new fields of application (hyperspectral, LiDAR).

Composite UAV/UAS case study built from diverse technological solutions

Presently UAV and UAS applications are increasing all over the world. The unmanned solution presents several advantages for disaster management, whether for their flight flexibility (approach, change of direction) or with the limitation of the risk for operators in extreme situations (catastrophe undergoing, health hazards, too important contamination, unknown contamination level). The following paragraphs derivate from the work of Adams (2012), summarizing the most recent application of UAV in disaster situation. [31]

Collecting information when physical access is compromised by the damages - damage survey of road network with UAV imagery and video

Several applications of UAV were done after earthquake (Haiti) and cyclone (Ike, Wilma, Katrina) to survey the damage on infrastructure and in particular on the road network. [32] UAV appeared as one of the most adapted solutions when site access is compromised. The survey was done using a helicopter UAV with digital camera system able to perform both imagery and video. The UAV was equipped with GPS in order to be able to guide it to an AOI and let it hover in place when the operator wanted more detailed analysis on a place.

Another case reported the use of Helicopter UAV after the typhoon Morakot in Taiwan. Imagery was captured; calibration, photogrammetric techniques and triangulation were applied to produce quality digital elevation DEM that helped in the disaster restoration and reconstruction work. [33]

Collecting information when physical access is compromised by contamination level – survey at Fukushima

In March 2011 the Fukushima-Daiichi nuclear facility was damaged after Japan was hit by an earthquake followed by a tsunami. Because of the high level of radiation after the melting of 3 reactors and because workers had to be as few exposed as possible exposed to the radiations, aerial monitoring with UAV was employed. A Air Force Global Hawk UAV was mobilized on the area. It was equipped with IR sensors and guided the operator in their attempts to cool the reactors. A T-Hawk Micro Aerial Vehicle equipped with radiation sensors completed the reconnaissance and help the operator to localize the nuclear fuel debris. The T-Hawk UAV could acquire video and imagery at lower altitude. [35], [36], [37], [38]

Similarly to the T-Hawk, three French helicopter UAVs were equipped with camera and radiation sensors to support the monitoring operations. The fleet of UAV employed in this situation demonstrates one more time the necessity to gather complementary information (IR, video, imagery and gamma spectrometry) and shows how the limitations inherent to UAV was tackled (flying time limited to one hour in average).

Rapid aerial mapping response with semi-automated or fully automated maps creation.

The last trend we would like to introduce is the fully automated or semi-automated map production. Several companies and research introduced the present capacity with live mosaicking from aerial images or videos. [39], [40], [24] POI can also the marked during the reconnaissance. With the use information system which transfer the information in real time from the UAV to processing center and from the centre to operators in the field, is it possible to guide almost immediately the field operators to the priority target.

CONCLUSION

The study demonstrated that starting from the exhaustive list of the types of disaster and looking for each which information is relevant to collect by aerial means; it is possible to find application or airborne remote sensing for almost all the types of disaster.

The choice of the technology is technically driven, starting from the information to be collected (one or several sources), defining the accuracy required and setting the operational parameters (AAG, ground speed). The study also showed that a couple of technologies (LiDAR, RGB imaging, thermal, and hyperspectral imaging) can be successfully employed to cover almost all types of disaster. This has a strategic importance for disaster reconnaissance capacity building. A body responsible for disaster management and equipped with such technologies can handle reconnaissance for most of the situations.

Progress not only with the acquisition technology but also with processing capacities should be mentioned. The information support process should be considered as a whole because no deficiency (and delay) can be accepted in the case of catastrophe management. The apparition of live mosaicking and live transfer of information allow more flexibility and immediate response.

The case studies - selected to shows the most up to date trends - demonstrated that the combination of sensors for multi disciplinary approach is a key for a successful reconnaissance of disasters. Data fusion, dual sensors are becoming common. Another trend with the use of UAV/UAS allows more flexibility (with weather and with flight) and reduces the risks for the operator on extreme or risky disaster operation theatre. Real time information transfer, algorithm for real time geo-correction and the adaptation of the sensors to UAV platform will definitely reshape the reconnaissance approach in the coming years.

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