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The potential of aerial platforms in a 'rapid' emergency response context

Peter Spruyt, Guido Lemoine

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Contact information
Peter Spruyt
Address: Joint Research Centre, Via Enrico Fermi 2749, TP xxx, 21027 Ispra (VA), Italy
E-mail: peter.spruyt@jrc.ec.europa.eu
Tel.: +39 0332 786216

http://www.jrc.ec.europa.eu/

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The potential of aerial platforms in a ‘rapid’ emergency response context

1.0 Introduction

This report reflects on the potential use of aerial platforms in rapid emergency response contexts, typically following major disaster and crisis events. In Europe, a coordinated effort to provide mapping services to support emergency response operations after such events is part of the Copernicus programme, which facilitates the fast provision of thematic post-event map products based on satellite imagery. Increasingly, lightweight RPAS (Remotely Piloted Aircraft Systems) and lightweight UAV’s (Unmanned Aerial Vehicles) are providing operational capacities that render them attractive for consideration to bolster under certain conditions satellite-based services in support to emergency response operations. The latest developments show that lightweight RPAS and RVAS have clearly a mature market segment potential. The robustness and reliability of RPAS and RVAS systems are improving as well. However, in order to integrate their benefits in mapping services in support to emergency response, guidelines need to be developed on when, where and how to use RPAS and RVAS derived imagery.

However, we should also consider the option of using existing manned cartographic survey capacity. Major advances in this domain include the move to fully digital camera systems, the simultaneous use of multiple angular camera systems and integration with ancillary 3D mapping systems (e.g. LiDAR). The circumstances in which manned aerial survey is conducted are not always optimal: cloud cover, turbulence and air traffic control constrain the efficient use of the sensors, especially in European countries. Moreover, they cannot be used when the crew would be put at risk. These factors make the use of lightweight UAV technology an attractive alternative to manned aerial systems. On the other hand, manned aerial systems offer the best performance in terms of spatial and spectral resolution, they are very flexible in operation and all data that is acquired are available to the user as soon as the survey mission is completed. Quick deployment of manned aerial platforms is continuously improving due to the presence of important players in the market with several hubs in several European Countries. European coordination on service specifications, rapid deployment criteria and harmonized access to outputs is, however, not well developed and needs some attention.

Satellites are very stable platforms that orbit the Earth in a predictable way. Polar orbits allow (almost) global coverage, with revisit times of a few days. However, these overpass times cannot be changed, e.g. in function of the cloud cover. Pollution haze affects the image quality as well. For that reason, it can take a very long time before an area is completely imaged. One of the key issues in the operational Copernicus emergency management service is that consistent delivery of actionable map outputs within 24 hours after the request is not yet feasible, largely due to the latencies in satellite imagery tasking and acquisition.

In Table 1, some functional parameters are listed for comparison. An obvious advantage of aerial systems is the wider flexibility in resolution options and revisit capabilities. Some parameters are only indicative, and depend on a number of operational factors. For instance, the cost for (un)manned platform use comprises the cost for deployment to the area of interest plus the number of km2 to be mapped. For the (un)manned options actual cost per km2 depends on the resolution required and the total area flown. Satellite imagery suppliers usually use a minimum area for ordering (starting at 5 by 5 km2). Note that final output from aerial systems is typically ready to use in map systems. Satellite imagery usually requires additional ortho-rectification before such use.

Table 1. Comparison between functional parameters of satellite, manned and unmanned aerial platforms.

			
Parameter	Very high resolution satellites*	Manned cartographic surveys	Lightweight unmanned aerial vehicles
Area of interest coverage (km^2)	25-1000	100-1000	up to 10
Spatial resolution	> 50 cm	3 - 65 cm	5 - 20 cm
Deployment time (hr)	48 – 72, depending on cloud cover	24 – 48	< 24
Monitoring capability (revisiting time)	1-5 days	< 12 hr	< 2 hr
Overlap (for DEM generation)	Possible with some sensors only	Yes	Yes
Image quality	8-12 bit, visual and NIR	16 bit, visual and NIR	8 bit standard photography (incl. NIR)
License	Single or multi-user use of the data (not owned)	Data fully owned by customer	Data fully owned by customer
Price	10-40 €/km^2	10-100 €/km^2	10-100 €/km^2

* only optical sensors are considered.

2.0 Overview of Aerial Platforms Carrying Image Sensors

2.1 Manned aircraft setup

A **first** approach is to deploy a professional digital photogrammetric setup using large format or push-broom digital aerial cameras. Airplanes used for this kind of missions are typically twin engine survey aircrafts, equipped with camera holes in order to deploy various sensors (digital photography, LiDAR, thermal, etc.). This approach is obviously the right choice when there is a need to cover large areas with a superior radiometric and spatial quality.

Twin engine survey aircraft (copyright : Beechcraft king air)

Large format digital Vexcel Ultracam camera with accessories (copyright : Microsoft ultracam)

A second approach is using a strut mount equipped with a medium format camera (visual and near-infrared) that fits on the wing of a single engine aircraft. The advantage of this camera system is that it can be shipped to the project region (worldwide) and easily fitted to a single engine aircraft wing. This option is a valid solution for small to medium scale projects outside Europe in remote areas or difficult access conditions.

Strut mount (geovantage) on the wing of a CESSNA single engine. This system is FAA certified. (Copyright www.geovantage.com)

A common issue in all systems in Table 1 is the need for elaborate post-processing of the imagery following a number of digital photogrammetric steps. Without going into detail, it involves a number of sequential steps outlined below, which are computationally complex and, therefore, consume time. Satellite imagery is typically processed after acquired imagery is received at the ground station, taking between 30 minutes to several hours. Sophisticated manned survey platforms can perform these steps “on the fly”, i.e. the corrected imagery is available directly after the flight mission is completed (or can be beamed down via a radio connection).

GCP COLLECTION →FLIGHT/ORBIT PLAN→IMAGE-ACQUISITION (with GPS positioning) → POSTPROCESSING →DIGITAL ELEVATION MODEL → ORTHORECTIFICATION

2.2 Unmanned Aerial Vehicles (UAV)

UAV’s are generally classified into 2 main categories, which are fixed wing and rotary wing UAV’s. Fixed wing UAVs have the advantage of being able to fly at high speeds for relative long duration. Some fixed wing UAVs have the disadvantage of requiring a runway or launcher for take-off and landing and not being able to hover. On the other hand, rotary wing UAVs have the advantage of being able to hover, take-off and land vertically. They have however low speed and short flight range.

Note that lightweight UAV’s have limitations in flight time (30 minutes to 2 hours). Therefore, for covering large areas the typical photogrammetric setup using manned aircrafts is a valid and competitive solution.

Fixed wing Trimble UX5 (copyright : www. trimble.com)

Fixed wing Sensefly (hand launched) : (copyright : www.sensefly.com)

Microdrone md4-200 (copyright :www. microdrones.com)

This note will partially concentrate on lightweight fixed wing solutions and emphasis on the image output potential of software solutions in order to generate accurate ortho-rectified imagery and digital terrain (surface) models. Fixed wing solutions are suited for emergency situations for which a small area (up to 10 km2) needs to be covered with a high spatial detail (e.g. 10 cm). The deployment time of these systems is very short so timeliness is a positive factor as well.

How lightweight UAVs work?

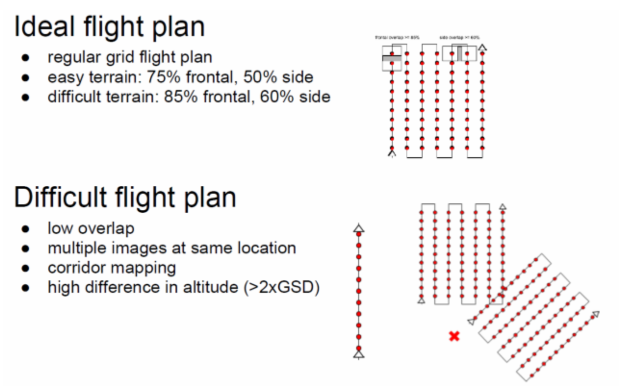
These light-weight fixed wing UAV's are following a typical photogrammetric process/workflow for ortho-image and elevation model generation. This process is similar to that needed for manned surveys, but is normally done after the flight (some UAVs can beam down uncorrected reduced resolution imagery via a radio link).

The bottleneck of these lightweight systems is the restricted flight time due to battery limitations. Most of the systems can handle easily a 45 minutes flight time. Important is to make an assessment of the Ground Sampling Distance (GSD) that is required for the imagery that is required for the emergency mapping activities.

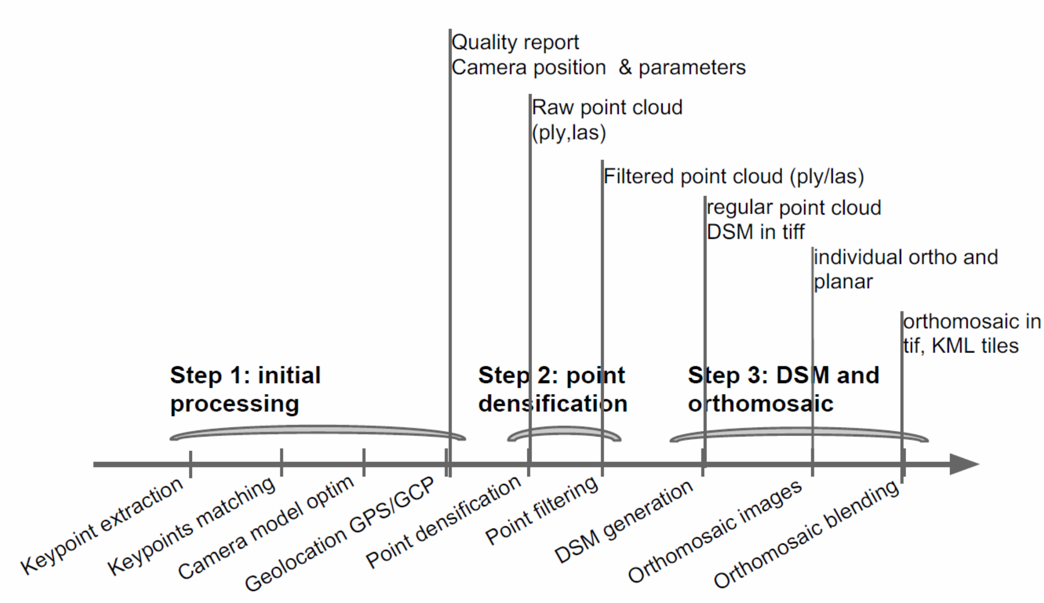
The GSD can be generated with the following parameters: image format, camera sensor size, camera focal length and the height above the terrain (flight height). The first 3 parameters are fixed. GSD is proportional to flight height (i.e. higher flight path result in larger GSD (i.e. lower resolution)).

For example: a Sony NEX-5 off the shelf camera with a 15 mm lens produces 16 Mpixel format images (4912 x 3264 pixels) with a camera sensor size of 23.4 x 15.6 mm (i.e. each camera sensor element has a size of 4.8 μm). At 300 m flight height, this results in a GSD of 9.6 cm (conversely, to get a 30 cm GSD, flight height should be approximately 900 m).

Speed is generally set to 13 m/sec. With the information on overlap and side lap all info is present to calculate accurately the flight plan. Note that each photo exposure needs to capture a GPS location on the same time.



The images and GPS locations are integrated in the post processing software and processed in less than 2 hour (for a typical flight of 40 minutes). Below an overview of the processing steps (pix4D).



3.0 Financial Impact of Manned and Unmanned Aerial Technology

The lightweight UAV technology described in section 2.0 has become a mature market component. A division should be made between the hobby segment and systems that address the minimum technical requirements of operational photo flights. A Sensefly EBee ready to go, with the post-processing software included, has an estimated cost of around 15.000 €.

The manned aircraft systems are operated by professional companies as they require an important financial effort to get operational and specialised staff to operate. The price for large projects covered by manned aircraft systems is however comparable to Very High Resolution (VHR) satellite ortho-rectified imagery.

An important operational consideration is related to the data rights. All imagery acquired with (un)manned aerial platforms is owned by the customer, who can then decide how to share the outputs with third parties. VHR satellite imagery is usually purchased under a license restricting the use to one or several users. Public release of satellite imagery is possible only at rather steep top-up fees and usually subject to the explicit agreement of the sensor operator.

Open source components are available for post-processing of UAV imagery. We estimate that with an increased use of UAV's the availability of functionally relevant open source applications will grow exponentially.

4.0 Technical, Operational, Legal and Environmental Considerations of Manned and Unmanned Aerial Technologies

4.1 Technical

The resolution of VHR satellite imagery is not always adequate for accurate, detailed, damage assessments in urban areas, for instance, after an earthquake. Quick deployment and a better ground sampling distance makes aerial imagery options (be it collected with UAV or with a classic setup) competitive in comparison to VHR satellite imagery.

Manned Aerial platform using a Vexcel ultracam: taken under cloud canopy, with a spatial and spectral resolution superior to VHR. The original GSD was 5 cm. The image is subsampled to 20 cm. Note how the absence of shadows is actually beneficial to damage detection. (copyright : blomcgr)

VHR Worldview2 image taken with a Very High Resolution Satellite Worldview 2.

Flood delineation derived from Synthetic Aperture Radar (SAR) satellite data in urban areas does not give satisfactory results and highlights the limitations of satellite-based approaches. This is particularly troublesome as urban and other infrastructure assets are typically the key focus of emergency response operations. UAV image sensors are a valid complement for this kind of damage analysis due to the ability of UAV camera sensors to operate under cloud canopy and because in most cases the scale extent (urban areas) is relatively limited.

UAV or other aerial platforms are operational alternatives to satellite imagery for disaster monitoring and damage assessment supporting:

- consistent impact mapping over a disaster area
- support response and recovery operations
- estimate objective reconstruction needs (Post Disaster Needs Assessments)
- rapid revisit opportunities (monitoring)

Disaster monitoring and damage assessments in remote areas with a serious security and safety issue can rely on bigger, more autonomous civilian UAV systems.

Copyright: www.barnardmicrosystems.com

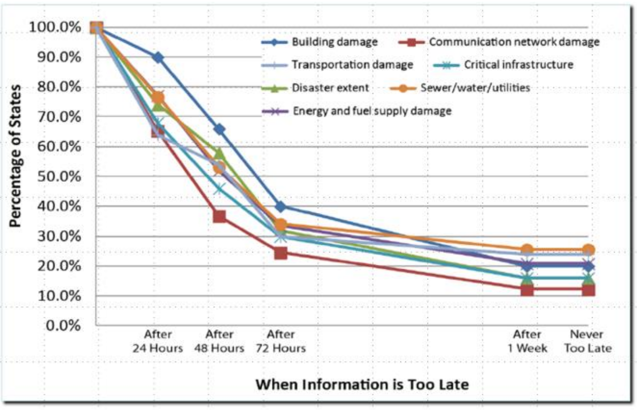
Such medium scale UAV technology has the advantage of covering larger areas. The system in the picture above (Barnard Microsystems limited) has a 700 km range and can carry up to 5 kg of camera equipment. The use of this option is particularly interesting in situations that require large surveys, but where manned platform deployment is difficult due to security reasons.

4.2 Operational set-up in Europe

A key decision criterion for using aerial platforms in an emergency response context is the deployment time. A study from FEMA[1] shows that useful actionable situation information (not raw data) needs to be integrated in the common operational organization within 24

[1] FEMA : Federal Emergency Management Agency (www.fema.gov)

hours after the event (90 % of the users indicate this threshold). After 72 hours, only 40 % of the end users claim that the data is still in time for operational integration.



Rapid deployment of European capacity in manned and unmanned aerial photogrammetry necessitates coordination between capacity hubs, detailed service specifications and a list of rapid deployment criteria. For manned aerial platforms a network of potential candidates can be listed. The criteria would include service level agreements that would guarantee fast deployment of the most suitable technical capacity (rapid response), the maximum operational range in a specific European region and very fast processing and delivery of the acquired imagery, for instance via web services.

Most of the European Countries have a private aerial survey company. The majority of them are small entities with one or two aircrafts equipped with large format cameras and LIDAR. Below you find a list with the largest companies capable of operating in several countries (note that other companies may fit the purpose)

- Aerodata International Surveys: The area of operation is Western and Southern Europe, Middle-East and Africa, but the aerial platforms are also deployed to projects elsewhere.
- EuroSense : has nowadays expanded its working region to mainly Western and Central Europe, but can live on experiences of worldwide projects.
- BlomAsa : area of operation is Europe.

For unmanned platforms the capacity can be built up gradually following the developments in the UAV market. We foresee in the near future that, acquiring and using an UAV will become more and more straightforward. In a first instance a European coordination effort may be envisaged to organise capacity building of National Civil Protection entities in using UAV's in their operational tasks.

4.3 Legal and Social Factors

In a staff Working Document by DG Enterprise "Towards a European strategy for the development of civil applications of Remotely Piloted Aircraft Systems (RPAS) (SWD(2012)259) published in September 2012, reports the outcomes of this consultation. Main conclusions were:

- RPAS (Remotely Piloted aircraft systems) present an important potential for the development of innovative civil applications (commercial, corporate and governmental) in a wide variety of sectors to the benefit of European society by creating jobs and achieving useful tasks.
- To unleash this potential the first priority is to achieve a safe integration of RPAS into the European air system as soon as possible.
- This requires the development of appropriate technologies and the implementation of the necessary aviation regulation at EU and national levels. Issues like privacy and data protection or insurance must also be addressed.
- It also requires an increased coordination between all relevant actors (EASA[2], national Civil Aviation Authorities, EURoCAE[3], Eurocontrol, JARUS[4], industry etc.) and between regulatory and technological developments.

However, recent developments in various Member States show that these benefits are poorly understood, and rather over-ruled by security and privacy concerns. One common complaint of UAV operators is that conditions vary widely between Member States from very restrictive (e.g. Netherlands, France) to relatively relaxed (e.g. Germany, Poland).

Given the urgency to achieve RPAS safe integration into the civilian airspace in view of the potential economic and social benefits of such applications, the UAS Panel called upon the European Commission to take the lead in the development of a Roadmap for safe RPAS integration into European Air System[5].

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[2] EASA : European Aviation Safety Agency
[3] EUROCAE : European organization dedicated to the development of technical standards in support of the aviation community.
[4] JARUS : JARUS is the Joint Authorities for Rulemaking on Unmanned Systems

4.4 *Environmental considerations*

Lightweight UAV technology operates on rechargeable and recyclable batteries, minimising their impact on the environment. Their electrical propulsion system has very low noise levels. Medium scale UAV's, although running on fuel, will consume much less than a manned aircraft. For example a Cessna Skyline needs 333 L for covering 1793 km, while a medium scale UAV (such as Barnard systems) needs 49 L for 2400 km. Another consideration is the raw materials that are used to build. Working on the same example as above, the Cessna Skylane needs 860 kg of raw materials while the medium scale UAV with 10 kg of payload needs 34 kg.

5.0 Conclusions and Recommendations

This short report serves as a quick review of the potential of (un)manned aerial platforms to service rapid mapping requirements related to emergency response operations. We have compared various performance parameters to show that such platforms can offer attractive benefits rendering them increasingly suitable to complement existing services, such as the Copernicus Emergency Management service which is based on the use of satellite imagery. This comparison shows that aerial platforms may yield significant benefits due to their higher flexibility in deployment, potentially better timeliness and more advanced technical capabilities, especially in situations that require detailed mapping of impact on high value assets. In particular, we have reviewed the use of UAVs in this context, as these are aimed at an emerging market of local applications. Of special interest is the lightweight UAV segment which combines required performance with reasonable initial cost of ownership, for consideration in practical response operations, both in Europe and international emergency situations.

In addition to addressing the urgent need to resolve the regulatory aspects of RPAS use, a number of activities should be developed at the European scale to better exploit the complementary use of aerial platforms in existing mapping services such as the Copernicus Emergency Management Service in support to emergency response operations. In particular, we recommend:

- A coordinated effort in developing the specifications of the technical and operational requirements for the deployment of (un)manned platforms in emergency response situations. The technical parameters should address minimum data quality, post-processing requirements, support to open data formats, including the possibility to deliver through internet-based data servers, event-specific imaging options, etc. Operational requirements should address common activation mechanisms, deployment parameters, timeliness of delivery, etc. The focus of these specifications should be on known cases where benefits of aerial platforms is considered most significant (e.g. urban related damage assessments, detailed damage/impact categorization);

- Definition of benchmark tests aimed at evaluation of the performance of existing and new aerial platforms, possibly leading to a certification scheme for operational emergency deployment. Tests may address technical parameter evaluation (e.g. image radiometric and geometric quality, 3D capacity, specific sensor use) as well as operational aspects (deployment scenarios, time-to-delivery). Tests should address as well realistic situations that may occur in emergency response set-ups. If these tests reach a sufficiently mature stage, integration with civil protection exercises could be considered;

- Provision of a platform for discussion on regulatory issues, technical evaluation, review of state-of-the-art, exchange of expertise in order to shorten the potential take-up of evolving techniques, address issues for the user community and facilitate exchange of European operational practical experience, possibly through twinning exercises. This platform could also play a role at international level, for instance, as the interface to the European user community in emergency response, deployment in international crisis situations that are of key European interest, etc.;

- Identification of programs at Member States' and European level, complementary to the Copernicus programme, that deal with deployment issues in an emergency response context and assist in the definition of common issues, best practices and R&D topics that need to be addressed.

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[5] RPAS : http://ec.europa.eu/enterprise/sectors/aerospace/uas/

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