Journal of Environment and Sustainable Mining Vol.1 No.2 (2025) 56-62

Journal of
Environment and Sustainable Mining

University of Sistan and Baluchestan

Iranian Society of Mining Engineering (IRSME)

Development of Drone-Borne Geophysical Surveys for Mineral Exploration

Reza Moezzi Nasab[*1], **Abolghasem Kamkar-Rouhani** [1], **Alireza Arab-Amiri** [1]

[1] School of Mining, Petroleum and Geophysics, Shahrood University of Technology, Shahrood, Iran.

ARTICLE INFO

Article type:
Review Article

Article history:
Received: 2025-04-04
Received in revised form: 2025-05-24
Accepted: 2025-06-22
Available online: 2025-06-29

Keywords:
UAV,
UAS,
RPA,
Drones,
Geophysics.

ABSTRACT

Drones, also referred as Unmanned Aircraft Systems (UAS), Unmanned Aerial Vehicles (UAV) or Remotely Piloted Aircraft (RPA), are aircraft without pilot on board. Currently the drones are used for geological and topographic mapping, coastal control, landslide inspections, etc., and are capable to integrate geophysical sensors like magnetic, electromagnetic, infrared, radar, natural gamma ray sensors and etc. UAS technology have several advantage over conventional airborne geophysics like resolution, accuracy, cost, etc. We are witnessing the birth of a new branch of aviation, which could be profitably applied to geophysics measurements.
In the modern-day advent of new technologies and methodologies in geophysics has become more important than ever before in acquiring better data from the Earth's subsurface. This advent has yielded a somewhat predicted fusion in the way geophysical data is acquired, by combining the power of Unmanned Aerial Vehicles (UAVs) and smaller, more hardware-integrated sensing equipment. Safety and cost considerations very play in the cause and effect of this culture shift in the realm of geophysics, whereas drones are more capable of flying closer to the ground, have greater vertical gradients, require less power for flight, and most evidently, the non-necessity of human collateral. Ultimately, drones should be, and to an extent is becoming, at least in geophysics, the way of the future.

Cite this article: Moezzi nasab, R., Kamkar-Rouhani, A. and Arab-Amiri, A. R. (2025). Development of Drone-Borne Geophysical Surveys for Mineral Exploration. Journal of Environment and Sustainable Mining, 1(2), 56-62. https//doi.org/10.22111/jesm.2024.47109.1009

Publisher: University of Sistan and Baluchestan.
DOI: https//doi.org/10.22111/jesm.2024.47104.1009

* Corresponding Author: **Reza Moezzi nasab**
E-mail Address: reza.m1371@yahoo.com

1. Introduction

The future prospects for drone technology in mineral exploration are incredibly promising. As technology continues to advance at an unprecedented rate, so too does the potential for using drones in geophysical surveys. These unmanned aerial vehicles (UAVs) offer significant advantages over traditional survey methods, including improved efficiency, accuracy, and cost-effectiveness [1-3]. Fig. 1 displays the time line of important developments of geophysical instruments, methodologies and the increase of computational power and the miniaturization of instruments through advances in micro electronic engineering. Drone geophysics benefits from this trend. Due to limited payload capacity and the limited flight time, drone geophysics relies on the ability to make the sensors lightweight. All rotary wing UAV allow flight times up to 30 min and payloads between 1kg and 10kg. In the future a swarm of drones will enable novel sensor configurations that will yield new resolution enhancement properties through multi-source multi-receiver combinations. One exciting advancement in drone technology is the development of high-resolution sensors and cameras that can capture detailed data from above the ground [4]. This allows for more precise mapping of mineral deposits and the identification of potential areas for exploration [5]. Additionally, drones equipped with advanced software and artificial intelligence capabilities can analyze this data in real-time, providing geologists and explorers with valuable insights and actionable information [6, 7]. Another area of advancement is the integration of different sensors and technologies into a single drone platform [8]. For example, drones can be equipped with magnetometers, spectrometers, and other geophysical instruments to gather a wide range of data. This multi-sensor approach provides a comprehensive view of the subsurface, enabling geologists to better understand the mineral composition and potential of an area. Furthermore, the use of drones in mineral exploration is not limited to above-ground surveys. Recent advancements in underwater drone technology have opened up new possibilities for exploring underwater mineral resources. These remotely operated vehicles (ROVs) can navigate deep waters, collecting data and samples from areas that were previously inaccessible [9]. As drone technology continues to evolve, we can expect even more advancements in the field of mineral exploration. Improved battery life and flight times will allow for longer and more extensive surveys [10]. Enhanced autonomous capabilities will enable drones to operate in challenging environments, such as dense forests or rugged terrains [11]. Additionally, ongoing research and development will likely lead to the creation of specialized drones specifically designed for mineral exploration purposes [1]. In conclusion, the future of drone technology in mineral exploration is incredibly bright. The advancements made in recent years have already revolutionized the way we approach geophysical surveys [12]. With continued advancements and investments in research and development, we can expect drones to play an increasingly vital role in unlocking the potential of mineral resources and driving the advancement of the mining industry [10].

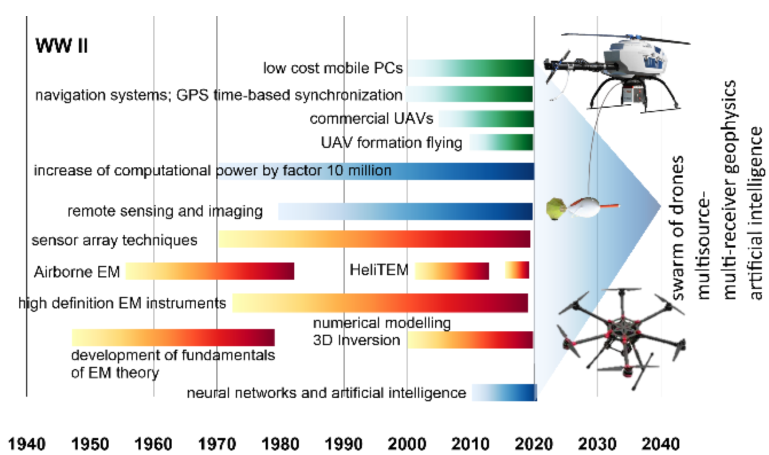

Fig. 1. Time line of key developments in drone geophysics [13].

2. Types of Drones

Drones have evolved in different configurations in order to develop different flight characteristics that could be exploited for various uses. The European Association of Unmanned Vehicles Systems (EUROUVS), according to their size, flight altitude, endurance and capabilities, has classified UAVs in several categories.

Micro and Mini UAVs have short range, limited endurance and limited payload. Tactical UAVs can further be subdivided into six categories: Close range (CR), Short range (SR), Medium range (MR), Long range (LR), Endurance (EN), and Medium Altitude Long Range (MALE). Close, short and medium range UAVs are limited in range by their communication line of sight. Strategic UAVs are bigger and heavier platforms usually used for high altitude, long endurance and long-range purposes. Special Task UAVs can be any of the above three categories which are used for a specific purpose. Drones can also be classified according to their shape into four different types: airships, flying-wing, fixed-wing and rotary-wing.

Airship drones are aircraft lighter than the air, similar to the conventional airships. These vehicles have massive size, long operating time but low cruising velocity. These types of drones are particularly suitable for use in enclosed and crowded spaces because little dangerous in case of overflight on people; in fact, their conformation avoids sudden and ruinous falls.

Flying-wing UASs are drones with high aerodynamic efficiency that can rise from the ground independently and exploit air currents for flying and landing upwind. The mechanism of flight, inspired by that of the birds is animated by a set of gear wheels and cams that transforms the rotary motion of a small electric motor into the swing motion of the wings.

Fixed-wing UASs are similar to airplanes. The fixed-wings provide aerodynamic lift, and then, for a given weight and engine power, allow to extend the operating time of the flight. This type of drones is suitable for applications where it is necessary to cover large areas. Conversely, these UASs require large space for the landing, but not always for the take-off, since some models can be directly launched in flight by hand or by means of small catapults. The main aerodynamics advantage for the fixed-wing UAS is the fuselage-wing. Fuselage-wing drones, thanks to a significant decrease in the aerodynamic drag and weight ensure the best performance in its category. However, the elimination of the empennage and the suppression of the drift imply a loss of directional stability, as well as some disruption in flight at low speeds, mainly due to the difficulty of applying the high lift of traditional flying wing. The best way to solve this problem is use of wings with sweep angles moderately accentuated. The fact that in a flying-wing drone the whole payload must be housed within the thickness of the wing can cause further difficulties: a wing with a profile enough to contain all the necessary facilities for the operation of the aircraft would have a front section so broad as to nullify the usefulness of the flying wing formula in reducing the resistance; for this reason, in flying-wing drone, the sensors are often housed externally to the profile [14].

Rotary-wing UASs are drones able of vertical take-off and landing, with capability of stationing in flight (hovering). The control of the main rotor allows these drones easily fling in all directions without limitation; this great flight control, however, is obtained at the expense of the autonomy of Near Surface Geoscience Turin, Italy, 6-10 September 2015flight. Miniaturization of the components needed for the scale production of a typical rotary-wing vehicle, has highlighted several problems. The helicopter main rotor, more than that of the tail, is quite dangerous owing to the exposure of the blades that are relatively large and therefore potentially harmful in case of impact. In addition, the tail rotor, in turn, constitutes a waste of power by accomplishing only the compensation function of the reaction torque of the main rotor.

A configuration that definitely remedies to the complexity of the chain of command of a helicopter is that of multi copter. This uses pairs of counter-rotating rotors to achieve the same stability without the need of the tail rotor for the contrast to the rotational movement caused by the main rotor.

3. Advantages and Disadvantages

The drawbacks of using manned aircraft can be numerous, however there are some main considerations. First and foremost, the safety of the crew members on board the vessel. The aircraft is operating lower than in normal flight operations, and the crew may be exposed to very rough terrain in very remote regions of the World. Another drawback of using traditional methods is the cost of operation. Given the number of crew members on board and considering their required skillset, there is a financial burden of employing staff, mobilizing them to the field, and other individual expenses potentially making up a large portion of the cost of performing a survey. These two considerations are reasonably the more malleable given the nature of the technological advancements that now exist in the realm of geophysics, and therefore an alternative, or multiple alternatives, can and have been developed to account for this malleability, creating an oasis for research and development in the desert of high cost and high safety concerns [15].

Unmanned Aerial Vehicles (UAVs) have existed for several years now and are more accessible than ever to a consumer market. The availability of these vehicles has stirred innovation in airborne geophysics. Industrial and educational researchers are working on optimizing the use of drones in geophysics (Fig. 2).

There are obvious benefits to using UAV technology in geophysical surveying. For the matter concerning the cost of operation and executing an airborne geophysical survey, commercial drones are generally less expensive than manned aircraft, however this is only valid for smaller drones, and not the very large military grade ones. Be that as it may, the relative excess cost taken on by having more sophisticated equipment is, to a variable degree, offset by the savings accrued by not having to hire on board crew for the UAV. Subsequently, the lack of human collateral on board the aircraft now means that the safety factor is significantly greater. This ultimately means that the aircraft can perform more risky maneuvers, and as a direct result of this, can have greater vertical gradient allowances compared to manned aircraft.

The use of drone technology for such undertakings requires heavy scrutiny, and rightfully so, to assert the feasibility of its performance in the field. A reasonable concern in field work is the endurance of the drone, and how many line kilometers can be flown per flight, as in, "how much production per unit time is ultimately achieved?". While smaller/lighter drones require less thrust from the engines to produce lift, it is also regretfully the case that these drones are equipped with smaller batteries, or smaller fuel cells resulting in shorter flight times, and ultimately lesser line kilometers flown per flight.

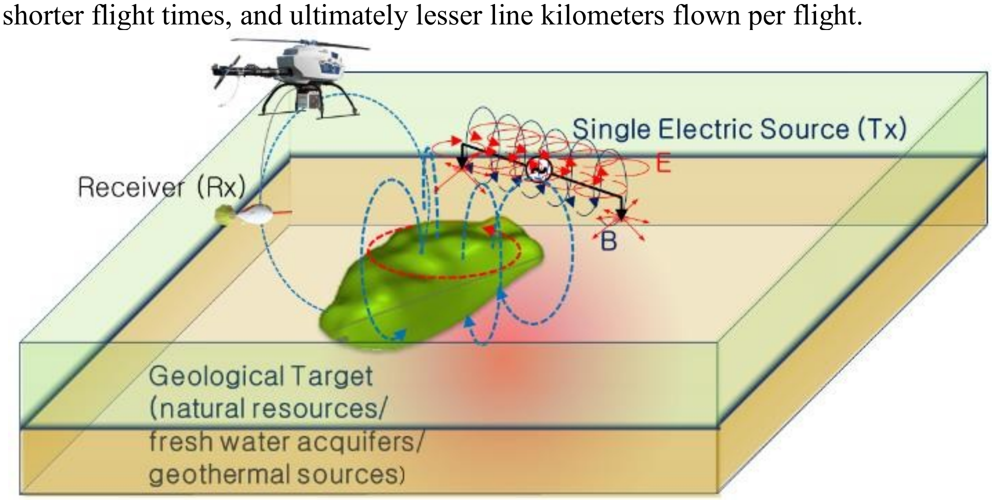

Fig. 2. Principle of Semi-Airborne Electromagnetics on a Multicopter [13]

Additionally, to the concerns of flight operations of the UAV itself, the geophysical technology that has been miniaturized to satisfy the payload criteria of the UAV is still short of delivering full capabilities given the sacrifices made to the accuracy, or even depth of penetration for active systems, such as electromagnetism. For mineral exploration, the equipment requires more development, thus rendering the equipment currently useless, hence companies are still forced to use manned aircraft to conduct the geophysical surveys. For agriculture, gamma ray spectrometry can be used to estimate soil moisture and soil composition, however, the accuracy of the measurements can decrease as the UAV systems are generally smaller than what is typically used on manned-aircraft.

UAS technology have several advantages over conventional airborne geophysics (Fig. 3):

- the resolution and accuracy are higher compared to the deployment of conventional manned aircrafts because UAS can fly much smaller ground clearance;
- it is cost effective and requires less personnel compared to conventional geophysical platforms;
- only the area of interest is flown; no excess flight lines are necessary.

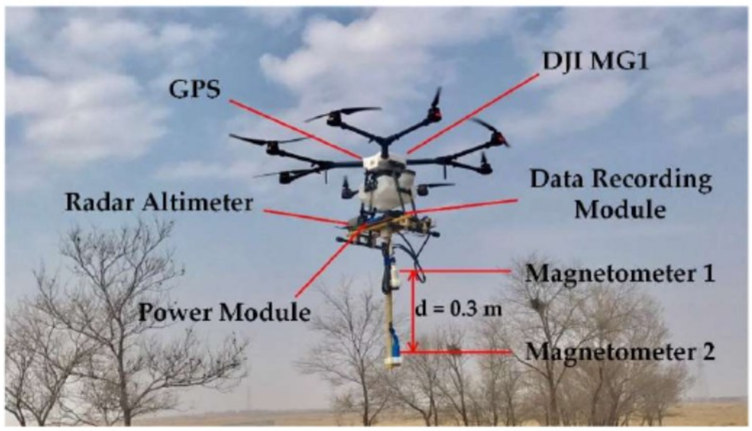

Fig. 3. The Unmanned Aerial Vehicle (UAV)-magnetometer system, carrying two magnetometers, radar altimeter, GPS, data recording and power module. The top magnetic sensor is labelled as magnetometer 1 and the bottom magnetic sensor is labelled as magnetometer 2 [16].

4. Results

using drone borne technology and geophysical methodologies to accomplish surveys investigating the subsurface of the Earth is not only a realistic thought, but one that has been applied and has produced convincing results that push for more research to advance the use of such combination of small devices and UAVs. Addressing the core issue of the importance of using UAVs in geophysics is just the tip of the iceberg, and still requires much development to yield an efficient, safe, and profitable method to execute airborne geophysical surveys, and this brief overview has presented why it is very reasonable to believe that using UAVs alongside geophysical technology is the way of the future.

5. Discussion

Unmanned Aerial Vehicles (UAVs) are increasing significantly in popularity in both the commercial and industrial senses. In the geosciences, airplanes and helicopters can be used to undertake geophysical surveys investigating the subsurface in search of resources such as minerals and water, and to monitor ground exploitation for agriculture. Aerial methods in geophysics are not new by any stretch of the imagination, however there are many sets of technological advancements that now allow for the miniaturization of these devices required to undertake surveys.

6. Conclusions

The drones allow the 'remote' location of a sensor, and to transmit the information, without the need to expose risks human life. Their ability to reach areas difficult / impossible to inspect from the ground, quickly and in a repetitive manner, allow to minimize inspection costs and avoid exposure of personnel to possible environmental risks. A specific drone must ultimately be chosen according to its own peculiarities in response to specific operating requirements. Ultimately, we are witnessing the birth of a new branch of aviation, which could be profitably applied to geophysics measurements, therefore is necessary prepare the players to the use the drone peculiarities for the future missions in order to allow a more effective and efficient exploitation of these new tools.

Ethical Considerations

The authors avoided data fabrication, falsification, and plagiarism, and any form of misconduct.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interest

The authors declare no conflict of interest.

References

[1] Pirttijärvi, M. and Korkeakangas, P. (2023). Drone-based electromagnetic survey system for environmental applications. EGU General Assembly 2023, Vienna, Austria, 24–28 Apr 2023, EGU23-11469. https://doi.org/10.5194/egusphere-egu23-11469

[2] Pauline, L., Maire, G., Martelet, J., Billy, N., Bernon, D. (2023). Magnetic surveying with UAV to fill the gap between ground and airborne magnetic surveys. 84th EAGE Annual Conference & Exhibition, European Association of Geoscientists & Engineers, Volume 2023, p.1- 5. https://doi.org/10.3997/2214-4609.202310563

[3] Pascal, F., Jacqueline, L. (2023). Increasing the accuracy and efficiency of wildlife census with unmanned aerial vehicles: a simulation study. *Wildlife Research*, 50(12): 1008-1020. https://doi.org/10.1071/wr22074

[4] Hitanshu, K., Anupam, B. (2023). Application of Artificial Intelligence in Drones for the Analysis of Agricultural Land Use in the Mining Lease. *International Journal of Enviornment and Climate Change*, 13(8):1606–1614. https://doi.org/10.9734/ijecc/2023/v13i82110

[5] Satyarthi, D., Arya, K. V., & Dixit, M. (2023). Drone Technologies: Aviation Strategies, Challenges, and Applications. In: Mohanty, S. N., Ravindra, J.V.R., Narayana, G. S., Pattnaik, C. R., Sirajudeen, Y. M. (Eds), Drone Technology: Future Trends and Practical Applications, pp. 117-152. https://doi.org/10.1002/9781394168002.ch6

[6] Prakash, K. L., Ravva, S. K., Rathnamma, M. V., and Suryanarayana, G. (2023). AI Applications of Drones. In: Mohanty, S. N., Ravindra, J.V.R., Narayana, G. S., Pattnaik, C. R., Sirajudeen, Y. M. (Eds), Drone Technology: Future Trends and Practical Applications, 153-182. https://doi.org/10.1002/9781394168002.ch7

[7] Gregory, U. S. (2023). Mineral exploration employing drones, contemporary geological satellite remote sensing and geographical information system (GIS) procedures: A review. *Remote Sensing Applications: Society and Environment*, 31: 100988. https://doi.org/10.1016/j.rsase.2023.100988

[8] Kim, J., Lee, J., Yang, E., & Kang, S.-J. (2023). Technology forecasting from the perspective of integration of technologies: Drone technology. *KSII Transactions on Internet and Information Systems*, 17(1): 31-50. https://doi.org/10.3837/tiis.2023.01.003

[9] Bruno, F., Lagudi, A., Ritacco, G., Muzzupappa, M., & Guida, R. (2015). Opto-Acoustic Data Fusion for Supporting the Guidance of Remotely Operated Underwater Vehicles (ROVs). The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XL-5/W5: 47–53. https://doi.org/10.5194/ISPRSARCHIVES-XL-5-W5-47-2015

[10] Dang, T., Minh, N., Dung, B. (2023). Applications of UAVs in mine industry: A scoping review. *Journal of Sustainable Mining*, 22(2):128-146. https://doi.org/10.46873/2300-3960.1384

[11] Gloria, d. C. (2023). Resources for tomorrow - how airborne geophysics can contribute for the exploration of deep mineral deposits. EGU General Assembly 2023, Vienna, Austria, 24–28 Apr 2023, EGU23-8765. https://doi.org/10.5194/egusphere-egu23-8765

[12] Wang, J., Qiu, K., and Fu, J. (2023). An Application of UAV in Open-pit Gold Deposit Geological Field Mapping, EGU General Assembly 2023, Vienna, Austria, 24–28 Apr 2023, EGU23-4412, https://doi.org/10.5194/egusphere-egu23-4412, 2023.

[13] Stoll, J. B., (2021). Advances and future trends in drone-borne geophysics, First International Meeting for Applied Geoscience & Energy Expanded, pp:3053-3057

[14] Whitehead, K., Hugenholtz, C.H., Myshak, S., Brown,O., LeClair, A., Tamminga, A., Barchyn, T.E., Moorman, B. and Eaton, B. (2014). Remote sensing of the environment with small unmanned aircraft systems (UASs), part 2: scientific and commercial applications. *Journal of Unmanned Vehicle Systems*, 2(3), 86-102. https://doi.org/10.1139/juvs-2014-0007.

[15] Salman, M. (2017). UAVs and Geophysics: The Way of the Future. International Journal of advances in agricultural and environmental engineering, 4(1), ISSN 2349-1523, EISSN 2349 1531.

[16] Yaxin, M., Zhang, X., Xie, W., Yaoxin, Z. (2020). Automatic Detection of Near-Surface Targets for Unmanned Aerial Vehicle (UAV) Magnetic Survey. *Remote Sensing*, 12(3):452. https://doi.org/10.3390/rs12030452