SnT 2021

CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

CTBTO

PREPARATORY COMMISSION

Potential Application of Unmanned Aerial Vehicles for On-Site Inspection

VNIITF ROSATOM

D.A. Sagaradze, A.S. Dorosev, I.V.Markov
(RFNC-VNIITF, Russian Federation, Snezhinsk)

Ural Federal University named after the first President of Russia B.N.Yeltsin

V.A.Sapunov, E.D.Narkhov
(Ural Federal University, Quantum Magnetometry Laboratory, Russian Federation, Yekaterinburg)

ORAL PRESENTATION

As reported by the 51st Session of Working Group B (WGB), 2018

WGB noted that remotely operated vehicles (ROVs), while offering utility for OSI operations, raise several important issues that need to be considered by WGB at future sessions [1].

Relevant PTS documentation

- Project 2.12 “Potential of Remotely Controlled Measurement Platforms” [2] which was implemented under the OSI Action Plan 2016-2019 [3].
- 24th OSI Workshop report entitled “OSI in Different Environments and Events Other than Underground” (Southampton, United Kingdom, 12-16 November 2018) [3], which recommended to examine new measurement technologies and platforms and ROV in particular
- In 2020 the 54th Session of Working Group B (WGB-54) initiated the discussions of issue papers for the draft OSI operational manual, which covered the issue of using autonomous underwater vehicles (AUVs) and ROVs (Theme 11, Observables).

OSI techniques for aerial survey and design concept for UAV-based measurement system

According to paragraph 69 of the Treaty (1) Protocol several geophysical measurement techniques may be applied for aerial survey.

If one assumes that aerial survey for OSI purposes is based on UAV

the basic design concept for UAV measurement system for near-surface distance geophysical is based on the following pillars:

- reliable and trouble-free unmanned aerial system for geophysical survey;
- capability to obtain high-quality geophysical data;
- safety;
- economic efficiency *(not discussed in this paper).*

1 – Comprehensive Test Ban Treaty (CTBT)
2 – Unmanned aerial vehicle, special case of ROV

Major conditions for trouble-free and reliable operation are based on availability of the following items:

1) ground-based flight control station; 2) stable communication with UAV for its control; 3) communication channel for geophysical data transmission or possible saving and storage of this data on UAV board; 4) on-board global positioning system (GPS); 5) on-board video equipment (visual flight monitoring).

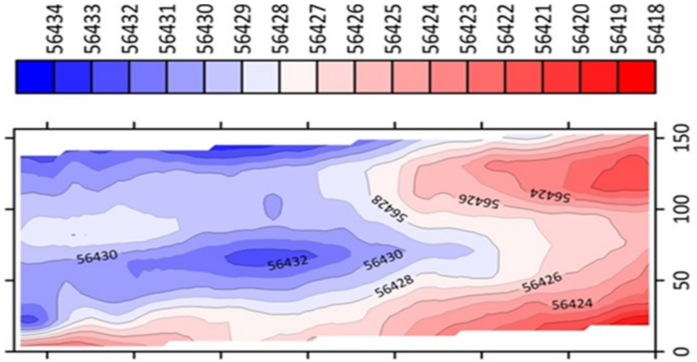
Major conditions for high-quality geophysical data

Accounting electromagnetic noises:

1) noises caused by ferromagnetic UAV design elements;
2) noises caused by operations of power equipment and electronic devices; 3) UAV vibration noises; 4) microphone effect noises caused by operation of UAV propellers.

Accounting noises caused with unstable spatial orientation: 5) UAV displacement caused with wind and positioning error; 6)Spatial deviation and rotations of geomagnetic sensor

An example is aerial magnetic field mapping based on experience of using Russian POS overhauser magnetometers: POS – 1 Aero and POS-2 Aero [6-11].

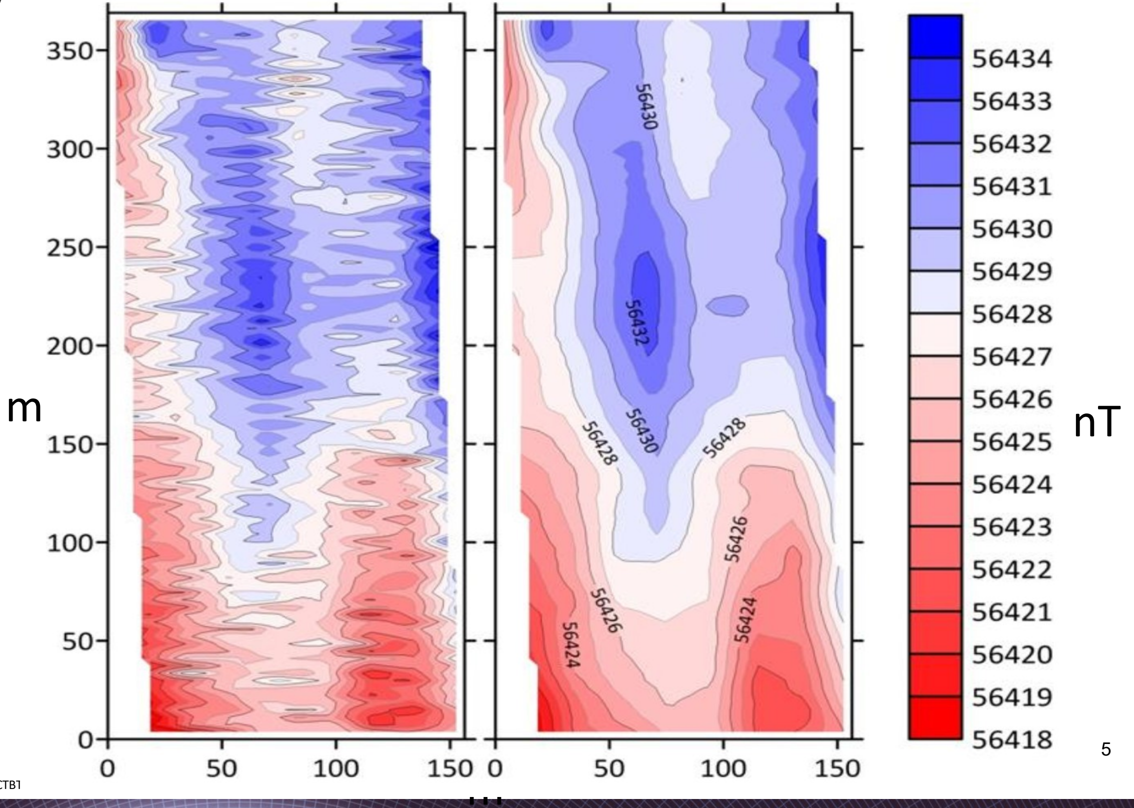


Major conditions for high-quality geophysical data (2)

Elimination of electromagnetic noises during data processing using mathematical techniques (noise filtering).

The figure presents the results of geomagnetic field mapping (magnetic induction full vector module):

- Flight height – 30 meters, flight speed – 5 m/sec;
- Left – raw (initial) data;
- Right – data, where the effect of electromagnetic noises is eliminated through mathematical data processing.



Major conditions for high-quality geophysical data

Technical solutions for noise prevention:

- special platform suspending electronics unit (magnetometer) to UAV(1), which reduces vibrations.
- special semi-rigid antigyroscopic sensor suspension (2) that prevents its high-speed rotation.

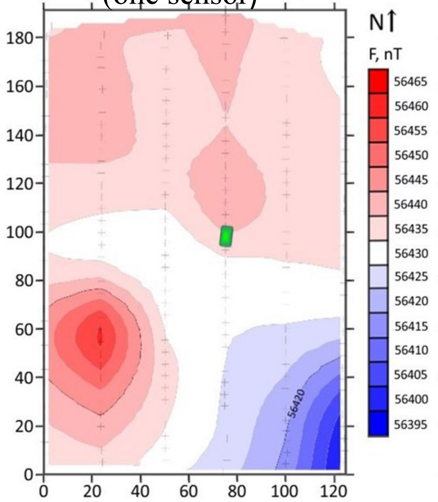
Major conditions for high-quality geophysical data (4)

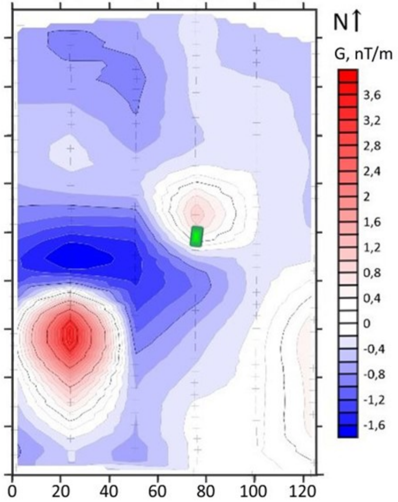
Methodological approaches:

- multiple flight lines en route in order to clarify geomagnetic field values;
- application of gradient survey (with several sensors in parallel) facilitates noise accounting and more effective identification of low-contrast anomalies;
- low and slow factor is a major unique feature of geomagnetic measurements [3];
- overflights shall have relief rounding;
- overflights shall cover areas localized during OSI (1 - 10 km^2).

Application of gradient-based survey: airborne gradient meter POS-2 Aero (two sensors)

(one sensor)





Safety procedures

- UAV safety concept provides training and high skills of pilots (UAV operators) for ground-based control station.
- UAV architecture shall be optimal and well-tested.
- UAV flights shall be included into common airspace in compliance with local legislation or international regulations.
- Flight missions shall be planned accurately with accounting weather conditions and local landscapes.
- UAV use in contaminated, hardly accessible and hazardous areas may enhance safety of inspection team members.

Legal aspects and limitations for UAV use

- Regulatory legal aspects of UAV use are very dynamic and far from uniform for different states [3]
- Lack of clarity in the Treaty provisions regarding potential application of UAV or remote platforms for OSI purposes.
- UAV status as equipment for OSI purposes is not determined yet.

Treaty Provisions	Method (type) of Measurements / Survey	Survey media	Treaty provisions for airborne application
p. 69 b) Protocol, Part II	Mutispectral imaging including infrared measurements	At and below the surface and from the air	On board the aircraft during additional overflights (p. 80 Protocol, Part II) *According to p 84 the aircraft is manned
p. 69 c) Protocol, Part II	Gamma radiation monitoring and energy resolution analysis	From the air and also at and below the surface	
p. 69 g) Protocol, Part II	Magnetic field mapping	At surface and from air in relevant cases	

Practical examination of the technique and comparative testing of relevant equipment are needed

Example of comparative testing:L'Aquila, Italy, demonstration of geophysical equipment, 2003 [12]

Yekaterinburg, Russia, testing overhauser UAV-based magnetometer POS-1 Aero, 2021 [10]

Conclusions

- **UAV-based geophysical measurement systems are being developed very rapidly and they have good prospects for effective application for geological and archeological missions.**

- **UAV application for OSI purposes requires resolution of the following issues:**

- Positive WGB decision on potential application of UAV (ROV) systems, determination of their application area and status as equipment;

- Each UAV (ROV)-based geophysical measurement technique for OSI purposes will have its unique technical and methodological features, that requires their practical examination and comparative testing;

- Final elaboration of OSI Operational manual and selection of equipment for UAV (ROV) techniques shall be based on the results of comparative testing and practical application in OSI conditions.

References

1. Report of Working Group B to the Fifty-First Session of the Preparatory Commission, CTBT/PC-51/WGB/1, 19 September 2018.
2. On-site inspection action plan for 2016-2019, CTBT/PTS/INF.1343, 11 December 2015.
3. Options for the application of remotely controlled platforms in an on-site inspection context, Project 2.12, CTBT/PTS/INF.1466, 6 August 2018.
4. Report of on-site inspection Workshop-24. OSI in different environments and events other than underground(Southampton, United Kingdom, 12-16 November 2018), CTBT/WS/OSI-24/1, 20 March 2019.
5. M.P. Semenova, V.S. Tsirel, *Perspectivy razvitiya bespilotnoi aerogeofiziki* (Prospects of unmanned aerogeophysics development) // *Razvedka i ohrana nedr* (Survey and protection of natural resources). — 2016 -№8. – pages 34-39.
6. Magnetometry Equipment List, Quantum Magnetometry Laboratory, Ural Federal University,https://fizteh.urfu.ru/ru/science/labs/seriinaja-produkcija/, 2021.
7. V. Sapunov, A. Denisov, O. Denisova, D. Saveliev, Proton and Overhauser Magnetometers Metrology Quantum Magnetometry Laboratory, Ural State Technical University, https://www.researchgate.net/publication/258217057_Proton_and_Overhauser_Magnetometers_Metrology, 2001.
8. V.A. Sapunov, A.Yu. Denisov, V.V. Saveliev and others, Modernization of ground-based overhauser POS magnetometers for application on unmanned copter-type aerial vehicles// *Inzhenernaya i rudnaya geophizika* (Engineering and mineral geophysics -2020) — Perm, Russia, May 12-16, 2020.
9. Tsirel Vadim, Parshin Alexander, Ancev Vasily and Kapshtan Dmitry, Unmanned Airborne Magnetic SurveyTechnologies: Present and Future, Chapter 36, DOI: 10.1007/978-3-319-90437-5_36, 2019.
10. Sapunov, V.A., Denisov, A.Y., Savelyev, V.V., Kiselev, S.E., Narkhov, E.D. and Sergeev, A.V., Modernization of ground-based overhauser POS magnetometers to use on small unmanned copter-type aerial vehicles. Conference Proceedings, Engineering and Mining Geophysics 2020, 1–8.
11. Parshin A.V., Budyak A.E., Babyak V.N. , Interpretation of Integrated Aerial Geophysical Surveys by Unmanned Aerial Vehicles in Mining: a Case of Additional Flank Exploration, International science and technology conference "EarthScience“, doi:10.1088/1755-1315/459/5/052079, 2020.
12. Demonstration of geophysical equipment…, Technical Report, CTBT/PTS/TR/2003-1, 2003. - 29p.