Explosive ordnance (EO) Multi-sensor Remote Detection System
based on two unmanned aerial vehicles (UAVs) with machine learning (ML)

Ensures the recognition of EO with a probability of at least 80% on a survey area of at least 1000 hectares

Concept
The multi-sensor remote detection system for explosive ordnance (EO) detection is designed for remote detection of explosive remanence of war (ERW) over large areas (at least 1000 hectares) with a detection probability of at least 80%. It is based on the use of two unmanned aerial vehicles (one for "hard load" (magnetic sensor) and one for "light load" (thermal and video cameras) for simultaneous use) with integrated / installed sensors and machine learning (ML) algorithms, which provide comprehensive real-time data collection, processing and analysis. The system combines a multi-sensor approach (video, thermal imaging and magnetic ground (surface) measurements) with high-precision positioning and cloud computing to create interactive maps of ERW contamination (exact location of detected / recognized munition and its' type labeling). The map will support evidence-based approach for follow up decision making process of humanitarian demining operations (type, needed assets, safety measures, logistics and limitations, etc.).

The system's operating algorithm:
1. Mission Planning (Planner + GIS)
2. Data collection (video, thermal, magnetic)
3. On-board processing (pre-analysis, filtration)
4. Data transmission (Starlink and D-RTK)
5. ML analysis (EO recognition, map building)
6. Visualization of results (interactive map, report)

System architecture
- **Level 1: 2*UAVs** + sensors (magnetometer, thermal imager, camera).
- **Level 2: Hardware and software integration module** + software for sensor integration.
- **Level 3: Positioning and Communication (**D-RTK 2 + Starlink for data transmission).
- **Level 4: AI Computing Unit (**Mission Planner + laptop with GPU).
- **Level 5: Cloud services** (ML software + servers with GPUs for analysis and mapping).

Main components of the system:
1. **Two UAV platforms for remote surveying/transporting sensors:**

1.1. UAV kit with a maximum payload of at least 2.7 kg (**DJI Matrice 300 RTK**, or similar); maximum flight time of at least 55 min; maximum take-off weight of no more than 9.0 kg; maximum flight speed of no less than 23 m/s; maximum wind resistance of no less than 15 m/s; maximum climb height of no less than 7,000 m; equipped with a control panel with a display of at least 5.5" and 1080p resolution, as well as a remote control operating time of at least 4.5 hours; with a signal transmission range of up to 15 km (FCC) / 8 km (CE); capable of setting up to 65,535 route points (Waypoint); with a built-in RTK module; with an operating temperature of -20°C to +50°C and a protection class of at least IP45; with 10 rechargeable batteries (**TB60**, or similar) with a capacity of at least 5,935 mAh and a voltage of at least 52.8 V; includes an intelligent battery charging station (**BS65 Intelligent Battery Station**, or similar), capable of simultaneously storing eight intelligent flight batteries (TB60, or similar) and four intelligent remote control batteries, with the ability to simultaneously charge several different batteries;

1.2. The UAV kit (**DJI Mavic 3T**, or similar) equipped with an omnidirectional viewing system up, down and horizontally; has a Max Takeoff Weight, no more 1050 g; Max Ascent Speed, no less 6 m/s (Normal Mode), 8 m/s (Sport Mode); Max Descent Speed, no less 6 m/s (Normal Mode), 6 m/s (Sport Mode); Max Flight Speed (at sea level, no wind) 15 m/s (Normal Mode); Forward: 21 m/s, Side: 20 m/s, Backward: 19 m/s (Sport Mode); Max Wind Speed Resistance 12 m/s; Max Take-off Altitude Above Sea Level, no less

6000 m (without payload); Max Flight Time (no wind), no less 45 minutes; Max Hovering Time (no wind), no less 38 minutes; Max Flight Distance, no less 32 km; Max Pitch Angle 30° (Normal Mode) and 35° (Sport Mode); Max Angular Velocity 200°/s; with Hovering Accuracy: Vertical: ±0.1 m (with Vision System); ±0.5 m (with GNSS); ±0.1 m (with RTK); Horizontal: ±0.3 m (with Vision System); ±0.5 m (with High-Precision Positioning System); ±0.1 m (with RTK); Operating Temperature Range: -10° to 40° C; remote control with a screen of at least 5.5 inches and a resolution of at least 1920*1080 pixels; equipped with GNSS navigation and safety system: GPS + Galileo + BeiDou + GLONASS (GLONASS active with RTK), RTK module integrated or attached; comprehensive obstacle sensors (APAS 5.0), ActiveTrack 5.0 and Advanced RTH (optimized return route); with **Wide Camera** – Sensor: 1/2-inch CMOS; Effective pixels: 48 MP; Lens: FOV – 84; Equivalent Focal Length: 24mm; Aperture: f/2.8; Focus: 1 m to ∞; ISO Range: 100-25600; Shutter Speed: Electronic Shutter – 8-1/8000 s; Max Image Size: 8000×6000; Still Photography Modes: Single – 12 MP/48 MP; Timed – 12 MP/48 MP; JPEG: 2/3/5/7/10/15/20/30/60 s; Panorama – 12 MP (raw image); 100 MP (stitched image); Video Resolution: H.264; 4K: 3840×2160@30fps; FHD: 1920×1080@30fps; Bitrate: 4K: 85 Mbps; FHD: 30 Mbps; Supported File Formats: Photo Format – JPEG; Video Format – MP4 (MPEG-4 AVC/H.264); **Tele Camera** – Sensor: 1/2-inch CMOS, Effective pixels: 12 MP; Lens: FOV: 15; Equivalent Focal Length: 162mm; Aperture: f/4.4; Focus: 3 m to ∞; ISO Range: 100-25600; Shutter Speed – Electronic Shutter: 8-1/8000 s; Max Image Size: 4000×3000; Photo Format: JPEG; Video Format: MP4 (MPEG-4 AVC/H.264); Still Photography Modes: Single: 12 MP; Timed: 12 MP; JPEG: 2/3/5/7/10/15/20/30/60 s; Smart Low-light Shooting: 12 MP; Video Resolution: H.264; 4K: 3840×2160@30fps; FHD: 1920×1080@30fps; Bitrate: 4K: 85 Mbps; FHD: 30 Mbps; Digital Zoom: 8x (56x hybrid zoom); **Thermal Camera** – Thermal Imager: Uncooled VOx Microbolometer; Pixel Pitch: 12 μm; Frame Rate: 30 Hz; Lens: DFOV – 61°; Equivalent Focal Length – 40mm; Aperture – f/1.0; Focus – 5 m to ∞; Noise Equivalent Temperature Difference (NETD): ≤50 mK@F1.0; Temperature Measurement Method: Spot Meter, Area Measurement; Temperature Measurement Range: -20° to 150° C (High Gain Mode) and 0° to 500° C (Low Gain Mode); Palette: White Hot/Black Hot/Tint/Iron Red/Hot Iron/Arctic/Medical/Fulgurite/Rainbow 1/Rainbow 2; Photo Format: JPEG (8-bit); R-JPEG (16-bit); Video Resolution – 640×512@30fps; Bitrate – 6 Mbps; Video Format: MP4 (MPEG-4 AVC/H.264); Still Photography Modes: Single – 640×512; Timed – 640×512; JPEG – 2/3/5/7/10/15/20/30/60 s; Digital Zoom – 28x; Infrared Wavelength – 8-14 μm; Infrared Temperature Measurement Accuracy – High Gain: ±2°C or ±2% (using the larger value); Low Gain: ±5°C or ±3% (using the larger value); has 8 rechargeable batteries in the kit type LiPo 4S (**DJI Mavic 3 Intelligent Flight Battery**, or similar) with a capacity of at least 5000 mAh ; operating temperature: -10°C … +40°C; is equipped with a remote control with a signal transmission range of up to 15 km (FCC) / 8 km (CE); comes with a battery charging station that can charge several batteries.

2. **External magnetic sensor module (magnetometer)** – a specialized device for remote measurement of the magnetic field (**SENSYS MagDrone R3**, or similar), powered by a 11.1 V lithium-ion battery with a capacity of at least 1950 mAh with an operating temperature range from - 20°C to + 50°C; weight with lithium-ion battery no more than 820 g; total power consumption no more than 500 mA; sensor tube dimensions (W x D x H) no more than 1070 x 22 mm; **flux gate** (**FGM3D/75**, or similar) with 2 sensors arranged horizontally, in parallel; measurement range ± 75,000 nT ; number of sensor axes no less than 3; distance between sensor center points no more than 1000 mm; noise level at 1Hz [pT / (Hz)]: 10 pT < sensor M1= 50 pT and 10 pT < sensor M2= 30 pT ; has **a data logger** , with power supply up to 50 mA ; equipped with a wired internal input from the sensor; the user interface is implemented with an on / off button + start/ stop and an LED status indicator; sampling frequency - 250 Hz ; internal memory - at least 8 GB; physical dimensions of the data logger (W x D x H) no more than 230 x 128 x 43/73 mm.

3. **Hardware and software integration module** for integrating various sensors on UAVs and implementing complex flight scenarios (**UgCS SkyHub 3**, or similar), powered by a UAV battery with an input voltage of 12-60 V, output voltage: 9 / 12 / 15 / 18 V, up to 5 A and additionally: +5 V and +12 V on communication ports for sensors; has interfaces: UART at least up to 4; RS-232 at least 2; GPIO at least 4 pairs; USB at least 2× USB 2.0; Ethernet 10/100 Mbit; Wi-Fi : Dual-band 802.11 b/g/n/ ac and Bluetooth : 5.0 (BLE); computing module on the platform: Raspberry Pi Compute Module 4; CPU Cortex-A72 (ARM v8), 64-bit, up to 1.5 GHz; RAM: 8 GB; Flash : eMMC 32 GB; OS: Ubuntu Server 21.04; mechanical parameters, dimensions no more

than – 112 × 84 × 34 mm and weight no more than 195 g (without mounts), ~215–220 g with mounts; operating temperature range from − 25°C to + 50°C.

4. **A computing unit based on a Laptop portable personal computer with artificial intelligence** (for training and processing neural networks) implemented on the basis of a portable laptop with a dedicated graphics card with characteristics not lower than: Intel® Core i7-13650HX processor, 14C (6P + 8E) / 20T, P core up to 4.9 GHz, E core up to 3.6 GHz, 24 MB; category of PC with artificial intelligence; NVIDIA® GeForce RTX™ 5070 graphics card 8 GB GDDR7, Boost Clock 2347 MHz, TGP 115 W, 798 AI TOPS; Intel ® HM770 chipset; 2x 16 GB SODIMM DDR5-4800 memory; two DDR5 SODIMM memory slots, with dual-channel support and expandability up to 32 GB DDR5-4800; 512 GB SSD M.2 2242 PCIe ® 4.0x4 NVMe ® storage; Two M.2 2280 PCIe ® 4.0 x4 storage slots ; with storage support for up to two drives, 2x M.2 SSD • M.2 2242 SSD up to 1 TB each; audio chip providing high-definition audio (HD), codec Realtek ® ALC3287; built-in 2W x2 stereo speakers optimized with Nahimic Audio ; microphone; 5.0 MP camera with electronic shutter; 60 Wh battery ; 245 W power adapter; LA1 artificial intelligence chip.

5. **Elements that provide, positioning of specified accuracy, data transmission and communication with servers / cloud storage**:

5.1. **High-precision GNSS** (Global Navigation Satellite System) **base station** (**D-RTK 2**, or equivalent), providing horizontal positioning accuracy ±1 cm + 1 ppm, vertical positioning: ±2 cm + 1 ppm , capable of supporting multi-frequency GNSS signals: GPS L1/L2, GLONASS L1/L2, Galileo : E1/E5a, BeiDou : B1/B2, with positioning update frequency: 1 Hz , 2 Hz , 5 Hz , 10 Hz , 20 Hz ; compatible with UAVs performing remote survey (item 1), portable; protected from interference and field conditions; powered by a lithium-ion battery with a capacity of at least 4920 mAh , providing up to 10 hours of operation; external power supply range: 10.5 - 28 V; Wi-Fi and Bluetooth ; radio transmitter range up to 10 km under ideal conditions; built-in memory up to 16 GB; degree of protection against moisture: IP67; operating temperature range from -20°C to +55°C, weight (with battery): ~1.2 kg.

5.2. **Equipment set for access to the global satellite Internet system from SpaceX** (**Starlink**, or similar), which uses thousands of satellites in low Earth orbit (LEO) to provide high-speed, low-latency internet. Typical download speeds are 50 to 250 Mbps, and latency is 20 to 50 ms. The user terminal includes a flat antenna with automatic guidance and Wi-Fi routers, which require approximately 50–75 watts of electricity.

6. **Power supply element** (**BLUETTI AC200P**, or equivalent) – a 2000 W battery charging station with a high-power AC inverter for 2000 W of continuous operation and 4800 W of peak power has a capacity of 2000 Wh, which allows you to provide energy to the equipment.

7. **Infrastructure – access to GPU servers** for processing big data and demining maps.
The use of machine learning / artificial intelligence to create a demining map implemented by:
1) All needed data previously collected for machine learning and artificial intelligence is trained for ERW recognition, can analyze in real time data from standard drones with factory cameras and industrial magnetometers.
2) Image and infrared processing with metadata, detection of mines and ERW on multiple images simultaneously, as well as on magnetic anomaly maps, with accurate plotting of findings in the coordinate system and interactive map.
Access to servers with GPUs for analyzing data from UAVs and recognizing GNPs with neural networks at the rate of 1000 hectares, engineering support and server maintenance.

8. **Software:**

8.1. Mission Planner (mission planning) – ground control software designed to plan, model and execute autonomous UAV missions, allowing users to define flight paths, configure sensor payloads (GPR or cameras, magnetometer, etc.) and monitor telemetry in real time. The platform should support

integration with GIS data, allowing for accurate terrain-aware mission planning for tasks such as mapping, inspection or mine-detection.

8.2. True Terrain Following (TTF) (Terrain-aware flights) True Terrain Following (TTF) is a licensed technology that allows UAVs to maintain precise altitude above the ground using radar or laser altimeters, without relying on digital elevation models, supporting terrain-aware flights at altitudes up to 0.5 m and speeds up to 20 m/s.

8.3. Artificial intelligence software for data processing – a neural network has been developed for visual recognition of ERW using UAVs, thermal and magnetic anomaly maps.