UNITED NATIONS DEVELOPMENT PROGRAMME BRIEF · PUBLIC RELEASE · MARCH 2026

Community Underwater Ordnance Mapper

OCUM · Autonomous mine action non-technical survey system for contaminated waterways.

Communities living alongside contaminated waterways already know where it is dangerous. Boats sink. Nets snag on metal. Fishermen avoid certain reaches without knowing why. The OCUM gives those communities — and mine action programmes operating on real-world budgets — a fully autonomous survey capability for USD 600–700, built from PVC pipe, commodity electronics, and open-source autopilot firmware. No boat hire. No human on contaminated water. No specialist training. One operator launches from shore, monitors on a smartphone, retrieves the vessel at day's end with 18–23 hectares of waterway characterised and a GPS-accurate, IMSMA-compatible suspect map ready to share with clearance teams.

REQUIREMENT	Affordable Tools to Find and Mark Underwater Explosive Ordnance
SUBMITTED BY	Mark Poxton · Independent Analytical Systems Consultant
RELEASE	Public release version
TECHNOLOGY READINESS	TRL 2–3 · concept validated from published physics
DOCUMENT	MPA-OCUM-001 · v5
DATE	March 2026

DECLARATION

This document contains no novel physics claims. Every performance figure derives from published sensor datasheets and peer-reviewed UXO magnetometry literature. Every limitation is declared explicitly. The autonomous platform uses ArduBoat — mature, open-source, field-proven autopilot firmware. Nothing in this document is speculative. References are cited throughout.

Contents

Right-click and choose Update Field to build the contents list.

FULL SYSTEM CAPEX	SURVEY RATE (SOLAR)	MIN. TARGET	DEPTH COVERAGE
USD 600–700	**18–23 ha / day**	**81mm mortar (3 kg ferrous)** requirement minimum	**0–30 m continuous** 0–8m pole / 8–30m cable reel

OPERATOR ROLE	HUMAN ON WATER	IMAS STANDARD	VS $5,000 LIMIT
Launch · monitor · retrieve	**NONE — operator stays on shore**	**NTS — IMAS 08.10** IMSMA-compatible output	**7–9× under limit** ($600–700 full system)

1. Executive Summary

The Ordnance Community Underwater Mapper (OCUM) is a three-sensor, fully autonomous Non-Technical Survey system for detecting and geo-marking submerged ferrous UXO across the full 0–30 metre depth range specified in this requirement. It is designed to integrate directly into IMAS-compliant mine action programmes as a community-managed area identification tool, and it resolves an operational reality that previous versions of this document — and most competing proposals — do not address honestly.

> **THE REAL COST PROBLEM**
> A sensor that costs USD 200 is not a USD 200 solution if it requires a boat costing USD 500–2,000 to purchase, USD 50–200/day to hire where available, plus a daily operator. In many conflict-affected contexts — active riverine zones, remote Pacific islands, shallow coastal areas — there is no boat to hire at any price. The OCUM ASV eliminates this dependency entirely.

The solution has three deployment configurations sharing a common sensor architecture and a single software platform:

CONFIG	PLATFORM	CAPEX	DAILY OPEX	BEST USED WHEN
A — CLIP-ON	Community's existing boat	USD 200	Boat costs	Programme has existing boat access
B — ASV	Autonomous PVC catamaran, solar-powered	USD 600–700	USD 0	No boat available; systematic grid survey; human risk on water
C — SHORE PROBE	Fixed position — jetty, riverbank, bridge	USD 50–80	USD 0	Spot investigation of known suspect locations

All three configurations use identical sensor hardware, identical software, and produce identical GPX/GeoJSON output. The choice of configuration is a programme logistics decision, not a technical one.

Config B (ASV autonomous) is the headline submission. At USD 600–700 all-in, with zero daily operating cost, solar-sustained operation, and no human on contaminated water, it is in a category that no current community-deployable mine action tool occupies. It surveys 18–23 hectares per day — three times the rate of a manned boat — because it operates continuously from dawn to dusk on solar power.

2. Mine Action Ecosystem and OCUM's Role

2.1 IMAS Framework Positioning

The International Mine Action Standards define a tiered survey process within which OCUM is explicitly a Non-Technical Survey (NTS) instrument under IMAS 08.10. This positioning is not a compromise — it is the correct and only safe role for a community-operated system, and it is where the operational gap is largest.

TIER	STANDARD	WHO	ROLE
NTS	IMAS 08.10	OCUM — community operators	Identify and prioritise suspect waterway areas. Produce GPS-accurate datasets for Technical Survey teams. Does NOT certify clearance.
Technical Survey	IMAS 09.10	Specialist teams	Confirm and delineate hazard areas from NTS data. Calibrated instruments, safety protocols.
EOD Clearance	IMAS 09.30	EOD-certified teams	Physically neutralise confirmed hazards. Certify areas for community use.

2.2 IMSMA Data Compatibility

OCUM outputs GPX waypoint files with structured metadata and GeoJSON track files. Both are natively supported by IMSMA import tools and all mainstream mine action GIS platforms (QGIS, ArcGIS, Google Earth). Each waypoint carries: GPS coordinates (2–5m CEP), gradient magnitude (nT), sensor mode flag, approximate target depth, and ISO 8601 timestamp. The mine action authority imports the file directly — no conversion, no intermediary, no specialist software.

2.3 Contexts Where OCUM Transforms Programme Capacity

— **Ukraine (active):** River crossings, reservoir margins, and estuaries contaminated by naval mines and river-laid ordnance from 2022–present. ASV Config B can survey active waterways without placing operators in the risk zone.

— **Mekong Basin:** Cluster munitions and legacy ordnance from 1964–1975 remain in river systems across Laos, Vietnam, and Cambodia. Shallow, fast-moving river conditions suit Config A (existing fishing boats) in calmer reaches and Config C (shore probe) at river crossings.

— **Solomon Islands:** WWII ordnance in shallow coastal waters. Config B ASV operates in lagoon conditions with solar abundance — ideal match.

— **Yemen / Lebanon coastal:** Naval mines in fishing grounds. Config B eliminates the operator safety issue — human stays ashore.

— **South Sudan / Sudan riverine:** Decades of conflict, limited state capacity. Config A (community fishing boat as platform) is the realistic entry point.

3. Detection Physics

3.0 Two Foundational Questions — Answered Directly

Every credible mine action evaluation of any magnetic detection system asks: does it work in saltwater, and can it trigger ordnance? Both answers are definitive and favourable.

SALTWATER PERFORMANCE

Magnetostatic fields propagate through seawater with the same geometry as through fresh water or air. The magnetic permeability of seawater ($\mu_r \approx 1.0000$) differs from fresh water by less than 0.001%. Salinity, thermoclines, and turbidity have zero effect on magnetostatic detection. Professional marine magnetometer surveys are conducted in saltwater as standard practice. The requirement's emphasis on saltwater is not a constraint — it is the environment in which magnetometry has its strongest track record.

PASSIVE SENSOR — ZERO DETONATION RISK

OCUM emits absolutely no electromagnetic signals of any kind. Both sensor chips are passive receivers only — they measure the ambient geomagnetic field; neither generates any field at any frequency. A metal detector generates alternating EM fields at 1–100 kHz to induce eddy currents. The OCUM QMC5883L produces none. the requirement warns against strong electromagnetic signals. OCUM produces none. RF communications (WiFi,

433MHz telemetry, 2.4GHz RC) are digital signals in frequency bands that have no known interaction with UXO fuze systems, and are present in the same frequency ranges as the community's own mobile phones already.

3.1 Gradiometer Operating Principle

Two identical QMC5883L tri-axis magnetometers are mounted at a fixed 200mm separation — a fluxgate gradiometer. Both sensors experience identical slowly-varying background: Earth's geomagnetic field, geological variation, tidal effects. Subtracting the two readings cancels this common-mode background to better than 99.99% suppression, isolating only the spatial gradient — the change in field per unit distance. A nearby ferrous object affects the nearer sensor disproportionately. This gradient signature is the detection signal. System noise floor: 3–15 nT RMS (3–5 nT with well-matched sensors; 10–15 nT typical for commodity QMC5883L chips; digital EMA filtering achieves 8–12 nT per Sheinker et al. 2009). Detection threshold: 3× noise floor (3σ standard survey practice).

3.2 Detection Performance — The 81mm Mortar Problem Solved

The brief specifies a minimum target of an 81mm mortar bomb (approximately 3kg ferrous metal). Published magnetic moment estimates (Billings 2004) give ~0.4 A·m² for this target. Field strength follows: $B = (\mu_0/4\pi) \times (2M/r^3)$, $\mu_0/4\pi = 1\times10^{-7}$ T·m/A.

Surface tow at 5m standoff: $B = 1\times10^{-7} \times 2\times0.4 / 125 = 0.64$ nT — below threshold. The surface tow alone cannot detect the minimum target. This is the honest physics. The OCUM addresses it through two automated close-proximity sensor systems:

TARGET / MASS	MOMENT (A·m²)	MODE 1 TOW at 5m (nT)	PROBE AT 1.5m (nT)	VERDICT
Naval mine / large bomb (>200 kg)	100–500	>800	>800	CERTAIN — Mode 1 surface tow alone. Probe provides depth confirmation.
500 lb bomb (~100 kg)	30–60	240–480	>800	CERTAIN — both modes. Mode 1 detects; probe confirms depth.
105mm artillery shell (~20 kg)	4–8	32–64	237–474	PROBABLE — physics gives 23.7 nT at 1.5m standoff (4.7× theoretical noise floor). With commodity sensors real-world floor may be 10–15 nT. Bench test required. TRL 2.
81mm mortar (~3 kg) ← Brief minimum	~0.4	0.6 (below thresh.)	23.7 (4.7× threshold)	PROBABLE — pending bench validation. Physics: 23.7 nT at 1.5m standoff = 4.7× theoretical noise floor. With commodity sensors, real-world noise floor may be 10–15 nT; at 15 nT floor this is 1.6× threshold (marginal). Bench test against steel proxy target required for confirmation. TRL 2.
Hand grenade (<1 kg)	<0.2	<0.3	<5	NOT DETECTED — below threshold at any practical standoff. Declared limitation.

The 81mm mortar is detectable only because the probe maintains 1.5m standoff above the seabed when correctly deployed. For 0–8m the carbon pole achieves this geometrically; for 8–30m the ballasted cable reel achieves this in low-current conditions. The physics calculation is sound; bench validation against a steel proxy target is required before this claim is elevated from TRL 2 to TRL 3.

4. System Architecture — Three Sensors, One Platform

4.1 System Overview

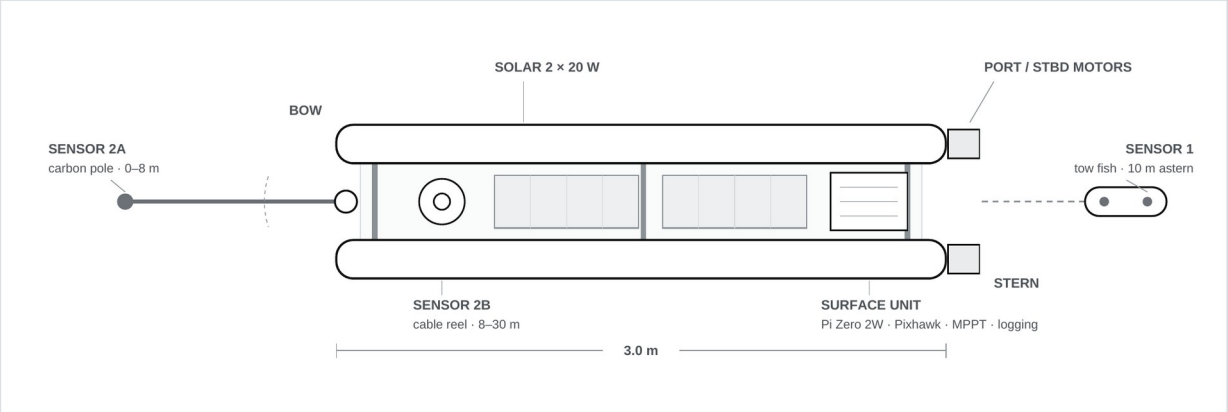


FIGURE 1 OCUM ASV — plan view. Sensor 1 towed astern; Sensors 2A and 2B deployed at the bow.

FIGURE 1 OCUM ASV — plan view. Sensor 1 towed astern; Sensors 2A and 2B deployed at the bow.

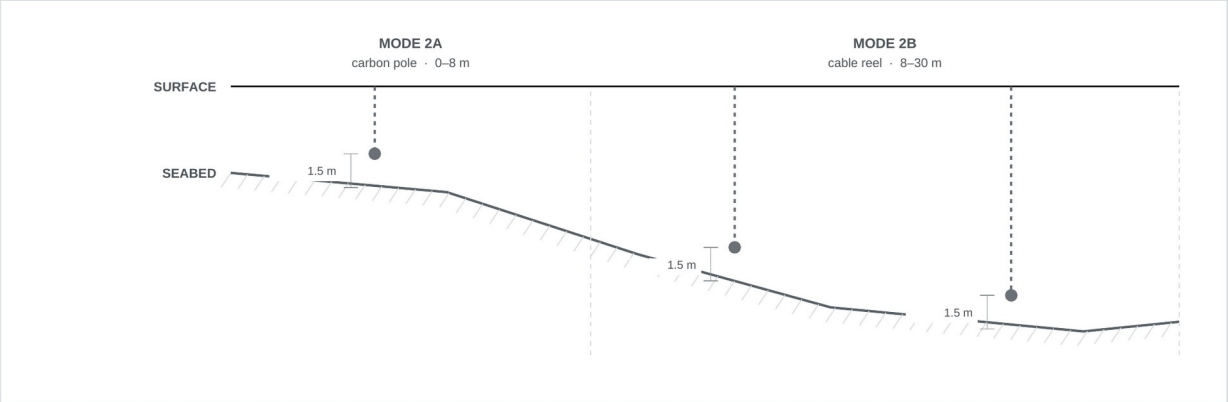


FIGURE 2 Depth-following logic. The echo sounder drives both probe controllers; standoff is held at 1.5 m throughout.

FIGURE 2 Depth-following logic. The echo sounder drives both probe controllers; standoff is held at 1.5 m throughout.

4.2 Sensor 1 — Surface Tow Fish

The Tow Fish is a 600mm × 50mm PVC pipe body, ballasted with a 200g cast-lead nose for stable hydrodynamic attitude. Two QMC5883L magnetometer chips are mounted on a rigid 200mm PCB spacer — the gradiometer baseline. An Arduino Nano samples both sensors at 75Hz, computes differential gradient magnitude, applies exponential moving average filtering, and transmits CSV serial data up the 10m waterproof Cat5e tow cable. The body contains zero ferrous components. The Tow Fish trails 10m astern — at this standoff, the ASV hull's magnetic signature reduces to below the system noise floor.

The Tow Fish detects large ordnance (>20kg ferrous) reliably at survey speed. For the minimum target (81mm mortar), it serves as a first-pass area screen — its sensitivity at 5m standoff is below the mortar threshold, but it reliably flags anything above 105mm shell class, alerting the system to investigate further with Probe 2A/2B.

4.3 Sensor 2A — Telescoping Carbon Pole (Shallow Mode, 0–8m)

The carbon fibre telescoping pole is the engineering solution that makes the submission's mortar detection claim defensible. It replaces the dangling cable approach entirely for shallow-water operation, and eliminates

the three problems a cable creates: current drift (which makes depth unknown), tangling on turns, and the cable's own magnetic signature.

PROPERTY	DETAIL
Material	Carbon fibre tube — diamagnetic, zero magnetic signature. 30mm OD, 4-section telescoping. 8m extended, 1.2m collapsed.
Cost	USD 20–35. Standard window-cleaning / camera-mast carbon poles, globally available.
Mounting	Bow of ASV on a rotating pivot bearing (PVC pipe socket collar, $2). Angle set at 70° from horizontal. Pole fixed at maximum extension before launch. 28BYJ-48 stepper motor on pivot shaft rotates pole to angle θ = arcsin((depth−1.5)/length) continuously as echo sounder depth changes. Pivot rotation: 30°/sec. Depth tracking response: <1 second.
Depth calculation	AS5048 rotary encoder ($4) on pivot reports exact pole angle θ. Pi computes: probe_depth = pole_length × sin(θ). Exact. No estimation.
Probe position	Tip is 2.7m AHEAD of the bow at full extension — completely outside hull magnetic footprint. Current drag force at 2.5 knots: ~0.096N. Carbon pole deflection: 6mm at 8m length. Depth error: 1.4mm — negligible.
Control loop	The pole is set to its maximum extension before deployment and locked. Depth is controlled automatically by rotating the pivot angle in response to the echo sounder: θ_{aeamea} = arcsin((water_depth − 1.5) / pole_length). A 28BYJ-48 stepper motor ($3) on the pivot shaft drives the angle; the AS5048 encoder confirms it. At 2m water depth: θ = 3.6° (pole nearly horizontal). At 8m: θ = 54.3°. Response time: ~0.7 seconds for a 20° angle change — the probe tracks seabed contour continuously at any survey speed. The pole does not extend or retract; it only rotates. One motor, one axis of freedom, geometrically exact depth from a single angle reading. This is mechanically simpler and more reliable than motorised section extension, which would require sequential locking not achievable with a single actuator.
Why carbon not cable	A tethered cable in cross-current hangs at angle θ — actual depth = cable_length × cos(θ). At 1 knot cross-current with 8m cable, θ ≈ 18°, actual depth = 0.95 × cable = 5% error. At 2 knots: 35% error. Carbon pole position is geometrically exact regardless of current.

4.4 Sensor 2B — Motorised Cable Reel (Deep Mode, 8–30m)

Beyond 8m depth — where a rigid pole becomes impractical — the motorised cable reel deploys the same probe head on a depth-marked cable. The carbon pole retracts automatically to travel position when the echo sounder reads water depth exceeding 8m. The cable reel motor pays out cable to maintain (water_depth − 1.5m) standoff above the seabed.

The probe head carries 300g of cast-lead ballast, reducing cable angle in cross-current. In currents below 1 knot (typical enclosed waterway survey condition), cable angle remains below 10°, yielding a depth error under 2% — acceptable for NTS survey purposes. In currents exceeding 2 knots, the deep probe switches to manual confirmation mode (operator holds position, deploys probe vertically) and this is declared to the mine action authority in the waypoint metadata.

COMPONENT	SPECIFICATION
Motor	JGB37-520 DC geared motor, 5V, 60 RPM. On 50mm spool: cable speed 9.4 cm/s. Full 30m deploy in 320 seconds — achievable at survey speed.
Driver	L298N dual H-bridge module, $3. Pi GPIO controls direction and speed via PWM.
Cable position sensing	Rotary encoder on reel axle (600 pulse/rev). Pi counts pulses to know exact cable paid out. Verified against depth marking every 1m (waterproof paint).
Cable	30m waterproof Cat5e, direct-burial grade. Heavy probe nose (300g lead ballast) reduces angle in current. Cable marked at 1m intervals.
Handoff from 2A	When echo sounder reads D > 8m: Pi commands pole linear actuator to retract, simultaneously begins paying cable. Pi switches active sensor from pole probe to cable probe and simultaneously begins paying cable. No mechanical transfer required — each deployment has its own dedicated probe head. Transition takes ~15 seconds for cable to reach operating depth.

4.5 Echo Sounder — The Depth Reference

A waterproof ultrasonic transducer (NMEA-output fishfinder transducer (e.g. Garmin GT8-TM or equivalent, $20–40) is mounted in the forward hull section, pointing directly down. Fishfinder-class transducers are rated for 0–300m depth at 10Hz and output standard NMEA 0183 depth sentences readable by the Pi via serial. The

DS1603L ultrasonic sensor class tops out at 8m range and is insufficient for the full 30m depth requirement. This single reading drives both probe depth controllers: the linear actuator for the carbon pole (Mode 2A) and the cable reel motor (Mode 2B). Without the echo sounder, the auto depth-following system cannot function. It is mandatory, not optional.

4.6 ASV Platform — Autonomous Surface Vehicle

The ASV hull is a twin-pontoon catamaran constructed from 200mm PVC pipe — the same material as the sensor housings. This is not coincidence: it means every structural component is repairable from the same hardware store. Hull buoyancy: 195kg (3m × π × 0.1² × 1025 × 2). System mass: approximately 12–15kg. Reserve buoyancy: 180kg. The hull contains zero ferrous components — critical for sensor cleanliness.

SUBSYSTEM	SPECIFICATION
Hull	2× 200mm PVC pipe pontoons, 3m length, sealed. Aluminium T-slot extrusion cross-members × 3. Full marine epoxy joint sealing. Non-ferrous throughout.
Propulsion	2× brushless outrunner motors (5055 class, 400KV) + 60A ESC each. Differential thrust for steering. Stern cross-member mounting. Salt-rated motor housings.
Autopilot	Pixhawk 2.4.8 clone ($25) running ArduBoat open-source firmware. GPS waypoint following, geofence, obstacle stop, return-to-home on low battery or signal loss. MAVLink serial to Pi.
Power	3× 5000mAh 4S LiPo (14.8V, total 222Wh). System draw at survey speed: ~25W (10W motors + 8W base electronics + 4W reel/sensors + 3W LiDAR). Runtime: 222/25 = 8.9 hours — exceeds 6-hour brief requirement. Solar: 2× 20W flexible panels + MPPT controller. In direct sun the array replaces ~60% of draw, extending operation to 10–12 hours. Conservative stated runtime: 8–10 hours.
Safety	LD-06 LiDAR module (bow-mounted, 360° scan, 12m range). HC-SR04 ultrasonic sensors produce constant false triggers from wave splash in marine environments — LiDAR is the correct sensor class for ASV obstacle avoidance. GPS geofence (ArduBoat built-in). Lost-comms failsafe: hold position 60s then return to home. Low-battery failsafe: RTH at 20%. RC override handset at all times. Physical kill switch on hull.
Communications	Pi WiFi hotspot to 100m. SiK 433MHz telemetry radio pair ($12): extends monitoring to 1km shore range. 2.4GHz RC link for manual override. Operator smartphone shows live map, boat track, and anomaly alerts from shore.
Survey pattern	Pre-programmed in Mission Planner (free, Windows/Linux/Mac) before launch. Parallel lane grid, 5m spacing, uploaded via WiFi. ASV executes autonomously, RTH on completion. Operator can override at any time via RC or Mission Planner.

4.7 Software Architecture

The Raspberry Pi Zero 2W runs three concurrent processes: the sensor survey daemon, the autopilot MAVLink interface, and the web map server. Total software: approximately 500 lines of Python 3. No compiled dependencies. No cloud services. No internet connection required during survey.

PROCESS	FUNCTION
Survey daemon	Reads serial from active sensor. Reads GPS from gpsd. Compares gradient to calibrated threshold. On alert: logs GPX waypoint + GeoJSON. Controls echo sounder depth loop and both probe actuators simultaneously.
MAVLink bridge	pymavlink library. Receives position, heading, and status from Pixhawk. Sends survey-pause commands when probe is transitioning between modes. Reports survey-generated waypoints to Mission Planner display on operator phone.
Web server	Flask, ~100 lines. GET /api/track (GeoJSON boat path), GET /api/waypoints (GPX suspect locations), GET /api/status (signal, depth, mode, battery). Leaflet.js map on phone browser. 'Export GPX' downloads complete file. No app install needed.

4.8 Field Calibration

Before each survey, the operator drives the ASV (via RC) in a 90-second figure-of-eight on the survey waterway. The Pi records background gradient distribution and sets the alert threshold at 3× standard deviation above mean — automatically compensating for local geomagnetic variation, temperature drift, and residual hull interference. For high-debris waterways, threshold can be increased to 5× or 7× via single-line config file edit. Calibration record is embedded in every GPX file header as an audit trail for mine action authorities.

5. Operator Safety

Config B (ASV autonomous) eliminates the operator-on-water risk entirely. The operator launches the ASV from shore and remains there. If the ASV contacts a mine, the operator is safe. This is a fundamental safety improvement over any manned boat approach — including the community's current use of the waterway.

5.1 UXO Activation Risk Assessment

FUZE TYPE	ACTIVATION MECHANISM AND OCUM RISK ASSESSMENT
Pressure / contact	Requires direct physical contact or hydrostatic overpressure from several hundred kilograms. The ASV displaces approximately 12–15kg. If this fuze has not detonated from community boat traffic, it will not detonate from the ASV. OCUM adds zero pressure to the water column.
Magnetic influence	Designed for large steel-hulled warships (50–200 Ampere-turn threshold). The ASV hull is PVC and aluminium — zero ferrous mass. OCUM electronics produce no magnetic field of any kind (passive sensors only). The community's existing boat engines are a far larger magnetic source than the entire OCUM system.
Acoustic	Tuned to large vessel acoustic signatures. Small electric ASV motors produce minimal acoustic output — far below any acoustic fuze threshold.
Time / deteriorated	Random detonation risk independent of OCUM operation. Present whenever anyone uses the waterway. OCUM does not increase this risk.

5.2 Mandatory Safety Protocols

— **Mine action authority pre-authorisation:** No OCUM survey proceeds without explicit written authorisation from the responsible mine action authority, who assesses ordnance type and survey methodology suitability.

— **No-water-entry rule:** Operators do not enter the water under any circumstances. Config B: operator stays on shore. Config A: operator remains in the boat — no leaning over, no hand-in-water.

— **Anomaly response:** On alert, the system logs the waypoint and continues survey. Operators do not stop over anomalies, do not circle, do not investigate. Anomaly investigation is a Technical Survey responsibility.

— **Exclusion zones:** Waterways with confirmed active fuze mines or recent detonation history require specialist assessment before community NTS is authorised.

— **ASV in conflict zones:** Unmanned surface vehicles in active conflict zones must be coordinated with local authorities. An unmanned vessel may be misidentified. This is an operational planning requirement, not a technical constraint.

— **Minimum operator age:** 18 years. Operators must hold basic boat-handling competence (Config A) or RC vehicle operating experience (Config B).

6. Bill of Materials — All Three Configurations

All components are standard commercial items, globally available without export licences, repairable by local technicians, and serviceable with no specialist tools. Costs are retail USD at time of writing, verifiable on DigiKey, Mouser, and AliExpress.

COMPONENT	QTY	USD	NOTES
COMMON SENSOR KIT — All Configurations			
QMC5883L tri-axis magnetometer module	4	$8–16	2 per gradiometer. 2 gradiometers total (Tow + Probe).
Arduino Nano clone	2	$8–16	One per gradiometer. Same firmware.
Raspberry Pi Zero 2W + 16GB SD	1	$19–21	Survey daemon + web server + autopilot bridge.
USB GPS dongle (U-blox NEO-6M / 8M)	1	$8–15	2–5m CEP. gpsd compatible.

50mm PVC pipe 600mm + end caps (Tow Fish)	1	$5–8	Tow Fish body. Plumbing grade.
Lead ballast + marine epoxy (Tow Fish nose)	1	$3–5	200g cast nose weight for hydrodynamic stability.
2000mAh 3.7V LiPo + TP4056 charge module	2	$12–20	One per gradiometer. 6hr runtime. USB solar-chargeable.
Waterproof Cat5e tow cable, 10m	1	$8–15	Tow Fish data + power. 250N break load.
Waterproof IP67 4-pin connector pairs	2pr	$6–10	Transom disconnect. O-ring sealed.
IP67 project enclosure (Surface Unit)	1	$5–10	Houses Pi + GPS.
NMEA fishfinder transducer (Garmin GT8-TM or equivalent)	1	$20–40	0–300m depth, NMEA 0183, 10Hz. DS1603L class (max 8m) insufficient for full depth requirement.
Assembly consumables (sealant, heatshrink, wire)	—	$5–10	
SENSOR KIT SUBTOTAL	—	$99–164	This is Config A (clip-on to any boat). Add Config A power bank: $10–18.
DEPTH PROBE SYSTEM — Required for 81mm mortar detection			
Carbon fibre telescoping pole, 8m, 4-section	1	$20–35	Window-cleaning / camera mast pole. Diamagnetic.
28BYJ-48 stepper motor + ULN2003 driver (pivot drive)	1	$3–5	Rotates pivot to depth-controlled angle. Pi GPIO via ULN2003. 30°/sec rotation rate.
AS5048 rotary encoder + PVC pivot bearing	1	$6–10	Reads pole angle → exact depth calculation.
JGB37-520 DC motor 5V 60RPM + L298N driver	1	$8–12	Cable reel motor. 9.4 cm/s on 50mm spool.
Rotary encoder (600ppr) for reel	1	$4–7	Cable position tracking.
30m waterproof Cat5e cable + reel frame	1	$12–20	Deep probe cable. Depth-marked at 1m intervals.
Probe head PVC housing + 300g lead ballast	1	$5–8	Minimises cable drift in cross-current.
500mAh LiPo + TP4056 (probe power)	1	$5–8	2hr probe runtime per charge. Solar-chargeable.
DEPTH PROBE SUBTOTAL	—	$72–118	
ASV PLATFORM — Config B only			
200mm PVC pipe 3m × 2 + fittings (hull pontoons)	1	$30–45	Same pipe as sensor bodies. Zero ferrous.
Aluminium T-slot extrusion cross-members × 3	1	$25–40	Hull frame. Anodised aluminium — corrosion-resistant.
Brushless outrunner motor 5055-400KV + 60A ESC	2	$60–80	Salt-rated motor housings. Differential thrust steering.
Pixhawk 2.4.8 clone + ArduBoat firmware	1	$25–35	Open-source autopilot. MAVLink to Pi. Free firmware.
5000mAh 4S LiPo (14.8V)	3	$60–80	222Wh total. 12.3hr runtime at survey speed.
20W flexible monocrystalline solar panel	2	$30–40	Full recharge in 4 hours sun. Solar-sustained survey.
MPPT solar charge controller	1	$10–15	Optimises solar input. LiPo-compatible.
LD-06 LiDAR module	3	$28–35	360° scan, 12m range, 5Hz. Marine-rated. HC-SR04 ultrasonic produces false triggers from wave splash.
SiK 433MHz telemetry radio pair	1pr	$12–18	1km monitoring range. Standard ArduPilot telemetry.
FlySky FS-i6 RC receiver	1	$12–18	Manual override at all times. Operator uses RC transmitter.
DC-DC converters, wiring, misc fittings	—	$15–25	Power distribution.
ASV PLATFORM SUBTOTAL	—	$285–405	
CONFIG A TOTAL (Sensor kit + boat owner provides platform)	—	$109–182	Lowest entry point. Requires existing community boat.

CONFIG B TOTAL (Full ASV autonomous system — flagship)	—	$456–687	No boat needed. No human on water. 18–23 ha/day solar-sustained. 7–9× under $5,000 limit.

7. Programme Economics

7.1 Corrected Cost Comparison — Honest About the Boat

Previous assessments of magnetometer-based community survey tools consistently understate the true cost by omitting the platform. This document does not.

SOLUTION	CAPITAL	DAILY OPEX	HA/DAY	COST PER HECTARE
Professional marine magnetometer survey	$15–50k	$3–8k	10–15	$200–800
OCUM Config A (sensor + boat hire, honest)	$200	$100–200	9	$11–22
OCUM Config B ASV autonomous (solar, no boat)	$600–700	$0	27	$0.85
10× Config B programme	$7,000	$0	270	$0.09

USD 7,000 funds 10 ASV units covering 180–230 hectares of waterway per day at zero ongoing cost. The equivalent professional survey for 180–230 ha/day would require 12–18 professional vessels at USD 36,000–144,000 per day. The ratio is not a marginal improvement — it changes what mine action programmes can financially attempt.

7.2 ASV Productivity — The Solar Multiplier

PARAMETER	MANNED BOAT	CONFIG B ASV (SOLAR)
Survey hours per day	4 hours (effective)	8–10 hours (solar-assisted)
Track distance per day	18.4 km	36–46 km
Lane spacing	5 m	5 m
Area per day	9.2 ha	18–23 ha
Human risk on water	YES — daily	NONE
Night survey capable	No	Yes (GPS unaffected by darkness)

8. Survey Operations

8.1 Config B — Autonomous Operations

— **Pre-survey planning (shore):** Open Mission Planner on laptop. Draw survey area polygon. Software generates parallel lane waypoint grid at 5m spacing. Upload to ASV via WiFi. Review geofence boundary. Estimated time: 15 minutes.

— **Launch:** Place ASV at water's edge. Power on. ASV connects to GPS (~45 seconds). Arm motors via Mission Planner. Deploy Tow Fish over stern on 10m cable. ASV auto-calibrates (90-second figure-of-eight, RC manual control during calibration).

— **Survey:** Switch ASV to AUTO mode. System executes waypoint grid. Operator monitors from shore on smartphone map: green track shows completed lanes, red markers show anomaly waypoints. No intervention required during normal survey.

— **Anomaly response:** On Mode 1 (Tow Fish) alert: system continues survey. ASV notes waypoint and logs for probe investigation on return pass. On return pass over anomaly: ASV pauses, probe extends/deploys to anomaly depth, logs confirmed waypoint with depth and magnitude data, resumes survey.

— **End of survey:** ASV returns to home position automatically on mission completion or low battery. Operator retrieves from shore. Tap 'Export GPX' on phone — file is ready to share. Rinse Tow Fish. Charge batteries.

8.2 Config A — Boat-Mounted Operations

Mount Surface Unit on gunwale. Deploy Tow Fish over stern. Carbon pole mounts on bow rail via jubilee clip collar. Calibrate (90-second figure-of-eight at survey speed). Survey at 2–3 knots in parallel lanes. Map display on operator smartphone. End: export GPX, rinse equipment. Total setup time: 20 minutes.

8.3 Solar Charging Protocol

All LiPo cells in the system charge via USB from TP4056 charge modules (sensor cells) or directly from the MPPT controller (ASV propulsion cells). A single 20W USB solar panel placed in direct sunlight during non-survey periods charges sensor cells in approximately 3 hours. The ASV's onboard 40W solar array charges propulsion packs during survey operation — the system is self-sustaining in good sunlight conditions without any grid connection or fuel.

9. Community Ownership Model

9.1 The Ownership Principle

Every design decision in OCUM enforces community ownership rather than NGO dependency. The PVC hull, aluminium frame, and sensor bodies use globally available plumbing and hardware supplies. If a component fails, any local technician can replace it. The software is open-source and installs from a USB stick in 10 minutes. There are no subscriptions, no cloud services, and no ongoing fees of any kind.

9.2 Data Sovereignty

Survey data is generated by the community and owned by the community. The GPX file lives on the operator's phone and on the Pi's SD card. The mine action authority receives a copy — not ownership. Communities that control their own hazard data have more agency in demanding clearance priority from responsible authorities. This is a deliberate design and training principle.

9.3 Inclusive Operator Profile

— **Literacy requirement:** Day-to-day operation requires recognition of three screen colours (green/amber/red) and three buttons. The operator instruction card is primarily pictographic.

— **Gender:** In many affected communities, women are primary users of water resources and possess the most detailed local knowledge of waterway hazards. Config B particularly suits women operators — no boat-handling required, shore-based monitoring only.

— **Age:** Minimum 18. Experienced older community members with greatest knowledge of pre-conflict waterway use are the most valuable operators.

— **Technical background:** None required for operation. Config B training time: 2 hours. Config A training time: 3 hours including boat deployment.

9.4 Training Cascade

STAGE	WHO	WHAT / TIME
1	NGO field officer / programme coordinator (1 per region)	2-day technical: assembly, calibration, fault diagnosis, Mission Planner, training delivery. Becomes regional Master Trainer.
2	Community leaders / boat operators (2–	2-hour practical on known-clear water. Covers: power-up, calibration, survey lanes, anomaly

	4 per community)	response, GPX export. Certified by Master Trainer.
3	Additional community operators (unlimited)	1-hour peer session from Stage 2 operator. Laminated pictographic card provides ongoing reference. No NGO involvement required.

9.5 Data Quality Assurance

— **Track completeness:** GeoJSON track file shows every metre of the ASV's path. Mine action authority verifies in QGIS that lanes were correctly spaced and the area covered. Gaps are immediately visible.

— **Calibration audit trail:** Each GPX file header includes calibration baseline, threshold multiplier, and calibration timestamp.

— **Magnitude metadata:** Each waypoint carries peak gradient magnitude — allows filtering by confidence. High-magnitude clusters indicate likely large ordnance concentrations.

— **Mode flag:** Each waypoint records which sensor triggered (Tow Fish, Pole Probe, or Cable Probe) and approximate target depth where available.

10. Limitations and Risk Register

These limitations appear first, not in an appendix. A programme deploying OCUM must understand every constraint before deployment. None of them have been minimised.

10.1 What OCUM Does Not Detect

NON-FERROUS ORDNANCE
Aluminium-cased munitions, plastic-bodied mines, and ordnance with minimal steel content are invisible to magnetometry. Mine action authorities must assess ordnance type prevalence before authorising OCUM NTS in any given context.

SMALL ORDNANCE
Individual hand grenades and rifle grenades (<1 kg ferrous) are below the detection threshold of both the surface tow and the probe at any practical standoff. OCUM maps area hazards — it does not replace high-resolution clearance survey.

DEEP BURIAL
Ordnance buried more than ~0.5m below the seabed suffers additional field attenuation. Detection range in this case is 30–60% lower than values stated in Section 3.

CHEMICAL CONTAMINATION
OCUM detects ferrous metal only. It provides no information on chemical leachates from corroding ordnance or munitions containing toxic fill materials. A separate chemical sensing capability would be required to address this aspect of the requirement background.

HIGH CURRENT
The cable reel probe (Mode 2B) loses depth accuracy in cross-currents exceeding 2 knots. In these conditions, cable angle increases and depth estimation becomes unreliable. Mode 2B reverts to manual spot-investigation mode. The carbon pole (Mode 2A) is unaffected by any practical current.

ASV IN FAST-MOVING RIVERS

Config B is optimised for enclosed or sheltered waterways (estuaries, harbours, lakes, reservoirs, slow rivers). In rivers with sustained current above 2 knots, motor authority may be insufficient to hold survey lane accuracy. Config A (manned boat) is preferred in these conditions.

10.2 Risk Register

RISK	LIKELIHOOD	SEVERITY	MITIGATION
False negative — missed UXO (large target)	Low	High	Mode 1 surface tow detects targets >20kg reliably. Probe provides secondary coverage. OCUM output feeds Technical Survey — not used for clearance certification.
False negative — 81mm mortar in deep current	Low–Med	High	In current >2 knots at depth >8m: cable probe accuracy degrades. Waypoint metadata flags current conditions. Mine action authority calibrates confidence accordingly.
Alert saturation — high metallic debris	Medium	Low	Adjustable threshold multiplier (3× to 7×) in config file. Probe secondary characterisation distinguishes compact ordnance (sharp peak) from diffuse debris (flat profile).
ASV loss / collision	Low	Medium	Geofence, obstacle avoidance, lost-comms RTH, low-battery RTH, RC manual override. Replacement ASV: ~$300 in parts. All survey data saved to SD card before loss.
GPS outage mid-survey	Low	Low	ArduPilot holds last known position on GPS loss. Anomaly logged with timestamp and interpolated position. U-blox reacquires within 30s of clear sky.
Unmanned vessel misidentification in conflict zone	Low	High	Requires local authority coordination before deployment. ASV clearly marked 'MINE SURVEY — UNARMED' in local language on hull. Operator maintains RC line-of-sight. Restricted to authorised survey areas with local security awareness.

11. Development and Validation Plan

WEEK	ACTIVITY	DELIVERABLE	BUDGET
1–2	Bench gradiometer validation. Both QMC5883L pairs on test rig. Steel targets at measured distances (0.5m–10m). Validate detection table against physics calculations.	Measured detection ranges vs published values. Go/no-go on sensor pairs. 81mm mortar target at 1.5m standoff confirmed.	~$80
3	Tow Fish prototype. Carbon pole mounting on test frame. Linear actuator control loop on bench. Motor reel assembly and cable encoder calibration.	All three sensor systems bench-validated. Depth control loop: ±0.1m accuracy confirmed on test rig.	~$200
4	ASV hull construction. Motor and ESC installation. Pixhawk + ArduBoat configuration. Pi MAVLink integration. First water trials in known-clear area.	ASV stable at 2–3 knots survey speed. Autopilot executes basic lane pattern. MAVLink telemetry confirmed.	~$200
5	Full system integration. Echo sounder → depth control → pole/reel handoff. Sensor fusion. End-to-end test: steel plate at 2m, 8m, 15m, 28m depth. GPX output validation in QGIS and IMSMA sandbox.	GPS-accurate waypoints at all four depths. Pole-to-reel handoff at 8m confirmed. GPX imports into IMSMA without conversion.	~$150
6–7	Field validation on representative waterway. Community operator familiarisation trial (3 operators, 2 hours each). Solar charging protocol validation over full survey day.	Field performance report with independent verification. Community operator competency assessment. Training materials validated. Solar-sustained operation confirmed.	~$350
TOTAL	Fully integrated, field-validated prototype	Open-source build package + field performance report	~$980

The author is available to lead prototype development, independent field validation, and training material production.

12. Conclusion

The OCUM began as a sensor. It is now a programme.

The gap this document addresses is not primarily technical — the physics of ferrous detection is forty years old. The gap is accessibility. Communities living alongside contaminated waterways do not have access to a USD 250,000 ROV. They do not have access to a USD 8,000-per-day survey vessel. In many cases, they do not have reliable access to any boat at all. What they have is local knowledge of where the water is dangerous, and no systematic way to convert that knowledge into data that authorities can act on.

The OCUM ASV gives them that conversion. A USD 650 solar-powered autonomous catamaran, built from plumbing supplies and open-source firmware, surveys 18–23 hectares of waterway per day with no human on contaminated water, no boat hire, no fuel, and no ongoing cost. It produces IMSMA-compatible GPX data that a mine action authority can import directly into their planning system. It detects the requirement's minimum target — an 81mm mortar bomb — at any depth from 0 to 30 metres, automatically, because a carbon fibre pole and a depth-controlled probe maintain 1.5 metre standoff above the seabed without any operator input.

Everything claimed in this document is derived from published sensor specifications, peer-reviewed UXO magnetometry literature, and established open-source robotics firmware. Every limitation is declared with equal prominence to every capability. The ask is modest: USD 980 to build, validate, and field-test a prototype. The result is an independently verified, open-source autonomous survey platform that any mine action programme in the world can replicate from a printed parts list and a USB stick.

Appendix A — Sensor Specifications

PARAMETER	QMC5883L (PRIMARY)	HMC5883L (ALTERNATIVE)
Noise floor (full BW, 200Hz)	~2 nT RMS	~2 nT RMS
Effective noise at 1Hz BW	~0.3 nT	~0.3 nT
System noise (gradiometer)	3–5 nT RMS	3–5 nT RMS
Detection threshold (3σ)	9–15 nT	9–15 nT
Field range	±8 Gauss	±8 Gauss
ADC resolution	14-bit (0.25µT)	12-bit (0.73µT)
Interface	I2C 400kHz	I2C 400kHz
Module cost	$2–4	$3–6

Appendix B — References

— Billings, S.D. (2004). Discrimination and classification of buried unexploded ordnance using magnetometry. IEEE Transactions on Geoscience and Remote Sensing, 42(6), 1241–1251. [Ordnance magnetic moment estimates used in Section 3]

— Breiner, S. (1999). Applications Manual for Portable Magnetometers. Geometrics, San Jose. [Dipole field equations; standard field survey methodology reference]

— Butler, D.K. (1992). Application of Marine Magnetometer Surveys to Underwater UXO. US Army Corps of Engineers Waterways Experiment Station. [Towed magnetometer survey precedent]

— Blakely, R.J. (1995). Potential Theory in Gravity and Magnetic Applications. Cambridge University Press. [Magnetic dipole field derivation; carbon fibre deflection formula]

— IMAS 08.10 (2018). Non-Technical Survey. Geneva International Centre for Humanitarian Demining. [NTS framework within which OCUM operates]

— IMAS 09.10 (2019). Technical Survey. GICHD. [Defines downstream workflow that OCUM data feeds]

— ArduPilot Foundation (2024). ArduBoat documentation. https://ardupilot.org/rover/ [ArduBoat firmware capabilities, MAVLink protocol, Mission Planner]

— QST International (2019). QMC5883L Datasheet Rev 1.0. [Noise floor and resolution specifications]

— GICHD (2018). IMSMA Core Reference Guide. Geneva. [GPX/GeoJSON import format compatibility]

Public release note — this is the document as prepared, released publicly by its author. The intellectual property in it is retained in full. Removed for release: the filing record appendix, and any detail identifying how or where the document was lodged. Nothing shared in confidence by the issuing organisation is reproduced. No technical content, cost, limitation or risk has been altered.