GICHD INNOVATION CONFERENCE

28-30 October 2025 | LUXEMBOURG

REPORT

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LIST OF ABBREVIATIONS

AI	Artificial intelligence
EO	Explosive ordnance
EORE	Explosive Ordnance Risk Education
FAIR™	Factor Analysis of Information Risk
IMAS	International Mine Action Standards
IP	Intellectual property
UAV	Uncrewed aerial vehicle
UNIDIR	United Nations Institute for Disarmament Research

INTRODUCTION AND FIGURES

Nearly 70 countries–one third of the world–remain affected by landmines and cluster munitions. The struggle to respond to the needs of affected people and communities is an everyday reality. At a time when conflicts and contamination levels are the highest since the Second World War, innovation in mine action is not optional; it is urgent.

For nearly three decades, the Geneva International Centre for Humanitarian Demining (GICHD) has worked for and with partners worldwide to make mine action safer, more efficient, and more effective. Innovation is central to this goal. It goes beyond technology. It includes new ways of working, strengthened partnerships, and tailored solutions for local contexts.

The GICHD Innovation Conference 2025 brought together mine action and ammunition management experts, practitioners, researchers and decision makers, eager for innovation. It provided a space for open and dynamic exchange, reaffirming commitments to strengthening innovation and connecting scientific insights with real-world field experience. By uniting people, technology, and collaboration it helps create a lasting impact in reducing the threats posed by landmines, cluster munitions and other explosive ordnance.

The conference reaffirmed a shared commitment: a world free from explosive ordnance risks, where communities thrive.

"The GICHD has been instrumental in translating the treaties into meaningful action, professionalizing the mine action sector, and driving innovation. Its expertise demonstrates how mine action has become increasingly feasible and safer, and its commitment to knowledge-sharing remains invaluable."

His Royal Highness Prince Mired bin Ra'ad of Jordan

ACKNOWLEDGEMENTS

The GICHD warmly thanks all participants, moderators, exhibitors, and partners for their invaluable contributions in bringing the conference to life. We would also like to express our appreciation to the Luxexpo The Box team for their professionalism in providing outstanding venue services and ensuring a seamless experience for all.

We are especially grateful to the Government of Luxembourg for hosting and supporting the event, and to the Governments of Switzerland and the European Union for their financial support, which made this event possible.

Co-funded by the European Union

LUXEMBOURG AID & DEVELOPMENT

Schweizerische Eidgenossenschaft
Confédération suisse
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Confederaziun svizra

Federal Department of Foreign Affairs FDFA

THE GICHD INNOVATION CONFERENCE 2025 IN NUMBERS:

Location: Luxexpo The Box in Luxembourg

3 days

20+ diverse and interactive sessions

30+ exhibitors

320+ participants

175+ organizations

55 countries

4 languages: Arabic, English, French, Ukrainian

CONNECTING TO THE NEEDS OF THE FIELD:

100+ participants coming from explosive ordnance (EO)-affected countries

75 speakers

30+ speakers coming from EO affected countries

9 sessions with National Mine Action Authorities speakers

INCREASING WOMEN'S VISIBILITY AND AGENCY:

80+ women participants

20+ women speakers

LEARNING FROM EACH OTHER:

110+ participants from outside of mine action

75+ participants from international organizations

90+ participants from research and technology providers

5 donors

GREEN TRAVEL:

GICHD staff reduced the event's carbon footprint by **2,500 kg of CO_2** by travelling by train instead of by air.

PARTICIPANTS FROM:

Angola
Armenia
Austria
Azerbaijan
Belgium
Burkina Faso
Cambodia
Cameroun
Canada
Colombia
Croatia
Democratic Republic of the Congo
Denmark
Estonia
Finland
France
Germany
Greece
Guinea-Bissau
Hungary
Indonesia
Iraq
Ireland
Israel
Italy
Japan
Jordan
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Lebanon
Libya
Luxembourg
Morocco
Netherlands
Norway
Poland
Portugal
Qatar
Serbia
Slovenia
Somalia
South Sudan
Spain
Sri Lanka
Sweden
Switzerland
Syria
Uganda
Ukraine
United Kingdom
United States
Viet Nam
Yemen
Zimbabwe

SETTING THE STAGE

Each week, academics, entrepreneurs, and startups find brilliant new ideas on how to improve mine action and ammunition management. There is no shortage of creative thinking, but the path from a great idea to real-world impact is a long one.

Discussions at the innovation conference serve as a compass, guiding creativity, science, and innovative minds toward the real-world challenges of mine action. The conference encourages the exchange of good practices, the recognition of failures, the celebration of successes, and the establishment of new collaborative partnerships.

Unfortunately, the number of landmine and cluster munition casualties is again on the rise. 2024 shows the highest annual number since 2020, and in Syria alone more than 1,400 casualties were recorded since December 2024. The mine action sector is at a challenging crossroads. Resources are decreasing, yet the need to protect civilians, restore livelihoods, and advance sustainable development is increasing.

> "For the civilians on the ground, the promise of innovation is not an abstract idea. It is hope of a life without fear. The realities on the ground demand that we work differently, that we work better."
>
> **Ambassador Tobias Privitelli, GICHD Director**

Responding to these pressures requires innovation in mine action that is focused on greater efficiency, effectiveness, and safety, which results in saving more lives. This includes innovation that strengthens how we apply standards and uphold normative frameworks, creating systems that learn, adapt, and improve over time.

ADDRESSING CHALLENGES TO INNOVATION IN MINE ACTION

Several obstacles hold us back. During the GICHD innovation conference in 2023, participants collectively identified five key challenges for innovation within the mine action sector. Here's how the innovation conference in 2025 engages with these challenges:

Limited funding and cost effectiveness

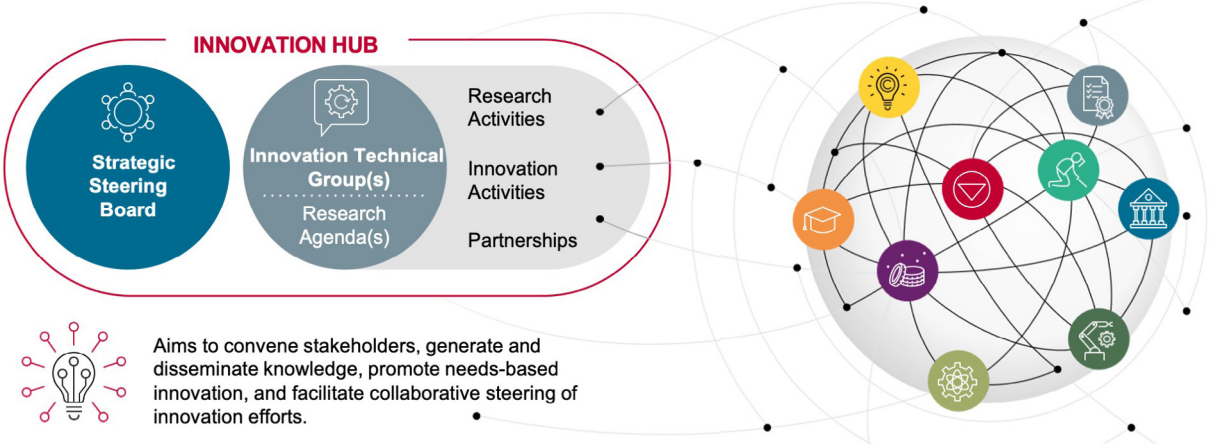
Mine action is an expensive endeavour, making innovation critical for enhancing cost-efficiency. Equally, dedicated funding for innovation is needed to ensure that new approaches can be adopted and brought to scale. This topic was a key focus of the conference, building on the emerging trend in increased innovation funding in mine action from both public and private donors.

"Silver bullet" bias and universal solutions

Innovation requires a mindset shift that takes us from searching for a one-size-fits-all solution to an approach based on the realities faced by deminers and people affected by explosive ordnance. Focusing on a "silver bullet" that works in every case distracts us from finding solutions that address real needs and contexts. The 2025 innovation conference put needs at the heart of the discussion, allowing participants to explore and understand the challenges in mine action prior to developing solutions.

Need for collaboration and coordination

Innovation in mine action is taking place, but not always in a coordinated manner. This leads to fragmented strategies, a duplication of efforts, and an inefficient allocation of resources. The GICHD's Innovation Hub fosters collaboration within the mine action sector and beyond, bringing together +100 organizations to share knowledge and support innovation. Members of the Innovation Hub helped shape the agenda and sessions of the conference in a way that showcases different perspectives, opening the door to new thinking and bold collaboration.



Perceptions of regulatory frameworks

As high-risk sectors, mine action and ammunition management are carefully regulated. While the International Mine Action Standards (IMAS) set out good practice, they do not create bottlenecks for innovation. Mine action standards are adaptable; they are developed by key actors in the sector and adapted to the realities of the field. The current review of the IMAS 07.11 on land release, which incorporates innovative survey technologies and methodologies, is a concrete example of how standards are adapted based on needs that were surfaced through past GICHD innovation events.

Resistance to change

Innovation has never been lacking in mine action, but for years the sector has shown pockets of resistance to change, with different actors choosing familiar routines over new, more efficient approaches. With funding for mine action decreasing, efficiency matters more than ever and every effort in the field must deliver the greatest return. Learning, sharing and building trust among stakeholders is the purpose of the innovation conference, eroding the mistrust that feeds resistance to change.

"We all share a goal–to make lives safer for the millions of people who face risks of explosive ordnance every day. Let's turn the promise of innovation into protection, recovery and resilience for millions."

Ambassador Tobias Privitelli

GICHD INNOVATION AWARD

In 2025, the GICHD Innovation Hub launched its first edition of the GICHD Innovation Award. Participants submitted papers with innovative ideas to address one of the two pre-defined problem statements on risk management principles:

- Improving the accuracy of estimating explosive ordnance hazardous areas; or
- Quantifying residual risk in land release.

These themes enhance the safety, effectiveness, and efficiency of demining operations which rely on evidence-based decision-making and application of "all reasonable effort" to ensure that land can be safely returned to communities.

The 57 submissions were evaluated by an independent panel composed of invited experts from mine action, scientific and technological institutions, together with the GICHD, based on the Innovation Hub Mine Action Innovation Technical Group, ensuring a diverse range of perspectives and expertise. The submissions were assessed on four criteria: innovation, feasibility, scalability, and impact.

The two winning submissions were announced during the Innovation Award ceremony during which they presented their innovative solutions. The awards were presented by His Royal Highness Prince Mired bin Ra'ad of Jordan and Ambassador Tobias Privitelli, Director of the GICHD.

By fostering divergent thinking connected to real-world needs and applications, the award creates a new channel to generate ideas and impactful innovation. It promotes the recognition of original scalable solutions, which can be integrated into existing mine action operations and frameworks.

★ AWARD FOR IMPROVING THE ACCURACY OF ESTIMATING EXPLOSIVE ORDNANCE HAZARDOUS AREAS

Japan International Cooperation Agency (JICA), Cambodian Mine Action Centre (CMAC), and NEC Laboratories Europe GmbH

Title: Exploring AI-assisted survey for humanitarian mine action: a pilot study in Cambodia

Abstract of the submission:

Cambodia remains heavily affected by landmines from decades of conflict, threatening lives and hindering development. Recently, newly discovered suspected hazardous areas, particularly in remote regions, have highlighted the need for more accurate and efficient survey methods, especially non-technical survey (NTS).

To address this challenge, the CMAC and NEC Laboratories Europe, with support from JICA, have launched a pioneering project integrating artificial intelligence (AI). Using CMAC's extensive operational data and NEC's technical expertise, the partners have created a country-scale humanitarian AI platform based on a "digital twin" mapping concept, to connect real-world data (sensor data, geospatial data, operational data, etc.) to the digital model. Specifically, the system analyses geospatial features such as roads, waterways, elevation, population density, and historical mine data to produce heat-map risk predictions that guide NTS teams.

Trained on thousands of data points, the AI model has achieved over 90 per cent agreement with real mine locations, improving efficiency, reducing costs, and enhancing safety. The platform is now undergoing field validation, with plans to expand its capabilities using additional field knowledge. Future validation is intended in other countries and data contexts, trying to prove the scalability of the approach, which could offer a groundbreaking model for mine-affected regions worldwide.

★ AWARD FOR QUANTIFYING RESIDUAL RISK IN LAND RELEASE

EODynamics AB and Matthew Hartung

Title: Applying the FAIR™ model to quantify residual risk in humanitarian land release

Abstract of the submission:

Applying quantitative risk methodologies from other fields, particularly the Factor Analysis of Information Risk (FAIR™) framework from cybersecurity, offers major potential to improve land release in mine action. FAIR™ provides a structured, data-driven way to assess complex risks where failure is unacceptable, making it well suited to explosive ordnance contamination. Its use helps challenge subjective or conservative traditional assessments and introduces stronger analytical rigour in the estimation of residual risk.

By integrating diverse datasets already collected in mine action–military records, community reports, historical incidents, and open-source information–FAIR™ uses probabilistic and data-driven methods for modeling, predicting, and reasoning under uncertainty (such as Bayesian inference, Monte Carlo simulations, and AI-based regression). This reduces uncertainty and delivers more defensible predictions of risk.

A feasibility assessment indicates that adapting FAIR™ to mine action is highly achievable; the required statistical methods are well established, data systems are already in place, and the framework scales easily across different contexts. Operational benefits include improved prioritization of surveys, more efficient resource allocation, lower costs, and iterative model refinement based on field outcomes.

Beyond efficiency, rigorous quantitative analysis strengthens safety, transparency, and community trust. By converting qualitative judgments into clear metrics, FAIR™ supports accountability, informs community engagement, and enhances compliance with humanitarian standards, advancing a safer and more effective global approach to land release.

SPOTLIGHT SESSIONS

In a new format for the 2025 innovation conference, two spotlight sessions showcased experts from outside the mine action sector, who delivered a keynote talk and participated in interactive question-and-answer discussions.

BEYOND THE MONEY: THE REAL DRIVERS OF INNOVATION

Maria Carolina Romero, angel investor

Securing the capital to turn a brand-new idea into an actual innovation can be a daunting task. Open-mindedness, creative collaboration, and the right pitch can put an innovator on the path to success. However, securing this funding is not the greatest obstacle to successful innovation–it is the humans behind the idea.

> "Financing alone doesn't move the needle; capital ignites, and mentoring sustains."
>
> **Maria Carolina Romero**

Creating a nurturing system for early-stage projects means ensuring new ideas aren't simply delegated to teams but are supported through mentoring and coaching. This often-overlooked factor can determine whether an idea fails or flourishes. What consistently makes the difference beyond capital, what gives real breakthroughs and multiplier impact are three main permanently intertwined factors: capital, coaching, and collaboration. In other words, the strength is not in the ability to fund a project or programme, but in the capacity to combine that with the appreciation of the genius that each stakeholder brings to the value chain, establishing an interconnected system that leverages the humans at the centre of innovation.

ARTIFICIAL INTELLIGENCE IN MINE ACTION: QUO VADIS?

Michael Tjalve, humanitarian AI expert

AI isn't truly intelligent. It doesn't think for itself; it's just capable of extraordinary guess work. AI is unbeatable in recreating, mimicking, and rapidly processing vast amounts of data. This is no small feature, and as such, AI is a very powerful tool. It's because of this, that it is critical to pause and reflect on the potential impacts of AI before becoming swept up in the excitement surrounding it. It's a tool we must steer with awareness and responsibility. Curiosity and caution towards AI are both welcomed.

> "The use of AI in mine action isn't just about smarter machines. It's about ensuring that every innovation is matched by intention, and that every deployment is matched by accountability. It's about making sure our smartest systems are guided by our deepest values."
>
> **Michael Tjalve**

Such an approach is critical within humanitarian settings, such as mine action and land release operations, where mistakes can have life-or-death consequences. It is therefore important to learn more about how AI works, how it generates recommendations, how it makes mistakes, so that the potential risks can be identified in context and proactively avoided or mitigated.

Beyond managing the risks, integrating AI within humanitarian frameworks demands ethical approaches that consider human rights, the legal remits of the protection of personal data and intellectual property, as well as the balance between donors' and investors' expectations and returns that are not purely financial. While AI holds immense potential for innovation in mine action, its success ultimately depends on ethical use, transparency, and sustained human oversight.

FUNDING INNOVATION

Cost-effectiveness and funding limitations are key challenges for innovation in mine action. Traditional funding mechanisms rarely provide flexibility, or accept the risk required for trying, testing, and learning innovative approaches. This is reinforced when innovative approaches focus too narrowly on technological developments and fail to demonstrate cost-efficiency.

Furthermore, mine action and ammunition management constitute, by default, small niche markets. Context-specific factors, including terrain, type of explosive ordnance (EO), geographical and environmental context, and national regulations, further fragment this already small market into even smaller segments. These factors represent some of the challenging conditions considered when seeking to attract investment to scale and sustain innovative methods and tools in the sector.

TAILORED FUNDING AND HUMAN CAPITAL

Innovation requires sustained investment over long periods, but different types of funding are required across the different stages of the innovation pipeline, as indicated by UN Global Pulse, Elhra, and the angel investor Maria Carolina Romero. Given the size of the markets and the risks associated with humanitarian innovation, blended models, such as co-investment schemes combining public funds with private investors or matching grants, hold the potential to reduce risk and increase scalability. Existing national and international research and innovation programmes need to be further leveraged to answer mine action and ammunition management needs.

Moreover, *"Innovation is not only about technology; it is about the individuals and the founders behind it."* (Maria Carolina Romero). It is about the intangible human capital of founders and innovators, carrying the motivation to turn ideas into impact. When leveraged with mentoring and coaching, which ensures the integration of new technologies within existing ways of working, innovation succeeds. Therefore, funding of impactful innovation needs to take into consideration the investment in human capital across the cycles of inception, prototyping, piloting, and scaling, as much as in the technology itself.

SCALING BEYOND PILOTS AND EXPLORING BUSINESS MODELS

Many innovations stall after the pilot phase, partly because funding mechanisms are outcome-focused and do not easily accommodate risk or long-term scaling. At the same time, while the localized nature of pilots can be more easily evaluated against impact metrics, scaling entails a much wider range of variables, particularly within humanitarian settings, making impact evaluation much more challenging, as the experience of UN Global Pulse and Elhra conveys.

So far, these unsolved challenges have been mitigated by the early involvement of potential adopters, tailoring evidence collection, and using incentive-based funding to encourage implementers to run trials.

Technology as a service business model, such as Humanity & Inclusion's project Odyssey2025, constitute another promising way of overcoming such scaling challenges. By funding not only the technology or single tools, but also the pooling and sharing of expertise with local actors, innovation can be sustainably scaled and deployed to support multiple operators in multiple settings. A shift deemed necessary as well by equipment manufacturers such as Global Clearance Solutions (GCS), who shared examples from Azerbaijan, Syria and Ukraine, where combining equipment deliveries with coordination with national authorities, non-governmental organizations, and local actors reduced duplication and maximized impact.

LEVERAGING INTELLECTUAL PROPERTY

Funding innovation often intersects with intellectual property (IP) management, particularly when it unlocks additional resources or partnerships. We should *"think of IP as an asset, not an obstacle, especially in the humanitarian sector."* (Lakshmi Supriya, World Intellectual Property Organization). Patents are built on the trade-off between sharing and protecting. On the one hand, they promote the dissemination of novel ideas, on the other, sustainable growth, equity, and shared prosperity.

Furthermore, while dissemination is always global, patent protection is time and geography bound, further balancing the trade-off. For example, the WIPO Technology SPARK Report on Technology for Mine Action, shows that between 2004 and 2024, over 3,500 mine action-related patents were filed, with detection technologies accounting for nearly half, mostly in China and the United States. Explosives detection, robotics, uncrewed aerial vehicles (UAVs), and sensors are emerging areas of interest. A relevant insight emerging from this patent analytics is that most filings are not protected in EO-affected countries, which could inform strategies for legally applying these innovations locally.

Academic, research, and technology organizations and startups, such as ETH Zurich and Sokil, typically secure IP to safeguard their inventions, strengthen their legal position and attract investors. However, securing IP does not, by default, dictate their approach to the wide range of IP agreements. Clear IP agreements are the mechanisms that ensure strong and equitable partnerships. These should be drawn up early on, with partner contributions recognized and licensing arrangements clarified in contracts, as Innovation Norway recommends.

Additionally, it is important to identify which partners are best qualified to manage and exploit the IP that is generated and can assume responsibility for its use and maintenance. Norwegian People's Aid presented a portfolio of R&D collaborations, where commercial companies retain ownership, while humanitarian organizations are granted free, non-exclusive licences for operational use. This balanced approach benefits all the parties involved, catering for the needs of humanitarian organizations and promoting scaling and wider sector adoption by commercial partners.

At the same time, there are noticeable trends towards open access, as communicated by ETH Zurich. Publishing raw experimental data in human- and machine-readable formats, alongside open-source software with clear licensing, enhances transparency, reproducibility, and trust while making output widely usable. Particularly from an academic standpoint, even if selected patent applications are intended to enable potential commercial use, the default orientation remains open, fostering collaboration and innovation.

HUMAN-CENTERED INNOVATION

Innovation is about impact and about people. Embedding people-centered, inclusive approaches throughout the innovation cycle is therefore essential. Only by doing so can new tools and methods meet the needs of survivors, communities, and actors in the field. Assistive technology, risk education, and messaging which aims to motivate safer behaviour of survivors and communities, are all key elements of human-centered design that can strengthen outcomes.

ACCESS TO ASSISTIVE TECHNOLOGY FOR SURVIVORS

Survivors of explosive ordnance face persistent barriers to mobility and independence, with assistive technologies often difficult to access and afford, even if the provision of accessible, affordable, and quality assistive technology is an obligation under international law, such as the Convention on the Rights of Persons with Disabilities, the Anti-Personnel Mine Ban Convention, and the Convention on Cluster Munitions.

In many cases, especially in rural and remote areas, these essential services are simply unavailable. Access to quality assistive technology is critical for dignity and inclusion, yet many survivors, particularly in conflict-affected areas, still lack reliable and sustainable services. Survivors often receive a prosthesis once, with no pathway for repair, replacement, or adjustment when the device wears out or becomes uncomfortable. Even when national disability policies and budget provisions exist, availability of resources, delays in the release of funds, import duties, costs, and limited and inaccessible infrastructure hinder implementation, as explained by the Ministry of Public Service, Labour and Social Welfare of Zimbabwe and the Implementation Support Unit of the Anti-Personnel Mine Ban Convention.

Technological innovations such as low-temperature thermoplastics, modular components, and 3D scanning enable flexible, context-appropriate prosthetics and orthoses. Digital design, paired with mobile workshops and remote training, allows production and mentoring to continue even in conflict-affected or low-resource settings. These solutions reduce dependence on imported materials, overcome infrastructure limitations, and extend service coverage to rural and hard-to-reach areas.

For such technologies to deliver impact, they must be part of a wider ecosystem, as the experiences of ATScale and Humanity & Inclusion reveal: innovation in products, manufacturing, workforce training, and service delivery must operate together. To meet growing needs and the integration of novel assistive technologies, it is critical to invest in more resources and innovation, and also essential to address the lack of national capacity, such as certified prosthetic and orthotics professionals in affected communities. Only by combining digital fabrication with formally certified local professionals can assistive devices be made sustainable and delivered in a dignified way.

TOWARDS MORE INCLUSIVE MINE ACTION

> "Exclusion in mine action isn't caused by one big barrier–it's hundreds of tiny ones built into the system."
>
> **Laura Scanlon, Here I Am Studio**

Behavioural science, design thinking, and peer-to-peer learning can strengthen inclusion by addressing the embedded barriers that limit participation. Lessons from other sectors–such as health, gender equality, and ammunition management–illustrate how these approaches can drive meaningful change to norms. And mine action practitioners can and often are very well positioned to contribute to positive norm change, provided such efforts are anchored in humanitarian and "do no harm" principles. Addressing underlying norms and attitudes is essential to overcoming resistance and ensuring that diversity, equality and inclusion become integral to sectoral practice. How? Empathy is a key word, as it drives behavioural change.

> "To change behaviour, people need to see themselves in the story. That's empathy. It makes change relatable and credible. When people see their own role models making the case for inclusion, it stops being someone else's agenda and starts being part of their identity."
>
> **Clément Meynier, Mines Advisory Group International**

RISK EDUCATION AND PREPAREDNESS: TAILORED MESSAGING

Innovation in Explosive Ordnance Risk Education (EORE) has taken multiple forms in recent years, ranging from low-tech and digital solutions to new methodological approaches such as social and behaviour change, all aimed at promoting safer behaviours and saving lives. In the context of rapidly evolving technologies, complex emergencies, and shrinking funding, there is a growing need to design risk education messaging more effectively and more efficiently, tailoring the messaging to wider differentiated target audiences faster. This need is exacerbated in current contexts increasingly characterized by insecurity, access restrictions, and limited resources for reliable and timely data collection.

This has led EORE and conflict preparedness and protection (CPP) to focus on leveraging open data sources, artificial intelligence, and open-source intelligence practice to collect, analyse, and design risk education messaging. Existing prototype systems such as the "CPP Monitor", a social media scraping tool presented by Norwegian People's Aid, and the concepts developed for the European Commission Horizon Europe Call for Proposals on humanitarian demining, showcase how such an approach could enable near real-time risk monitoring, dissemination of context-specific messages, and automated conflict-event analysis.

This approach highlights the sector's capacity to combine technology, behavioural science, and context-sensitive methodologies to enhance safety, preparedness, and protection in volatile and complex environments.

Other practical innovations demonstrated at the conference included gamified learning, digital training, and immersive media, illustrating how human-centered design can complement traditional EORE methods, making interventions more engaging, accessible, and effective for communities at risk. Digital solutions–including mobile apps, social media, augmented and virtual reality, and low-tech channels such as SMS, radio, and loudspeakers–allow practitioners to reach communities where they are and foster measurable behavioural change.

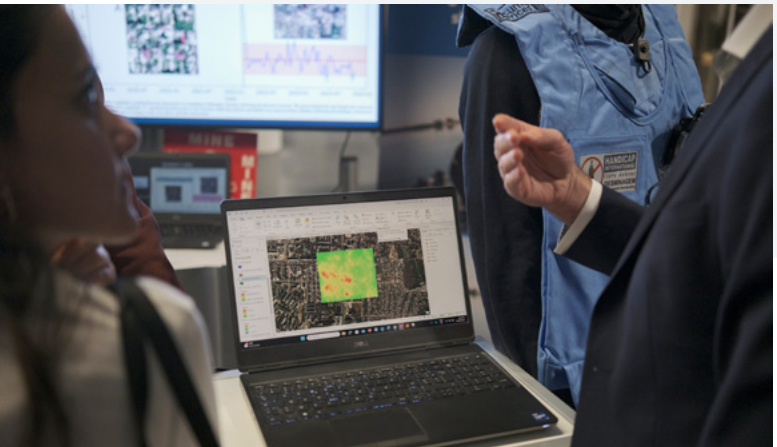
LAND RELEASE

Effectiveness, efficiency, and safety of survey and clearance remain essential drivers of innovative approaches. The challenge of more accurately identifying hazardous areas through survey, has been aided in recent years from the advance of UAV-based remote sensing. However, challenges remain in detecting subsurface explosive ordnance, particularly landmines, and in establishing workflows that enable broader adoption of these systems. The issue of discrimination for handheld detection systems remains largely unresolved, with false positive rates reaching as high as 80–1. Moreover, manual excavation of signals remains time-consuming, resource-heavy, and hazardous for deminers.

While no definite solutions can yet be provided, emerging tools and methods recently tested highlight important advances, as well as key bottlenecks. The former range from robotic excavation to UAV-based sensing and explosive substances detection.

LEVERAGING UAV-BASED SURVEY

UAV-based high-resolution red-green-blue (RGB) imagery caption has been proving effective when surveying areas with small surface-laid items with sparse low vegetation cover. This can lead to faster identification of hazardous areas, particularly if supported by AI-assisted imagery analysis, as shown by Norwegian's People's Aid experience in Ukraine. While hyperspectral imaging has also been investigated for surface detection, further research is still needed to prove it effective.



UAV-based subsurface detection remains challenging, particularly for small items such as cluster munitions or antipersonnel landmines. However, for larger metallic unexploded ordnance (UXO), UAV-based low altitude magnetometry and electro-magnetic induction survey have seen important advances. Such benefits were noted by the applied research work of the Demining Research Community of the University of Binghamton, New York, particularly regarding data processing, interpretation, and visualization.

Ground-penetrating radar and synthetic aperture radar (GP/SAR) systems, such as those tested by the Fondation Suisse de Déminage, also in Ukraine, have proven capable of detecting buried targets at typical application depths as well as surface-laid items in dense vegetation, in dry uniform soil conditions. While promising, such systems still present high levels of false positive rates, and require significant geophysical knowledge for the accurate analysis of results, which remains a major constraint for wider adoption.

While no single UAV-based sensor is universally effective across all contamination types, multi-sensor data integration as a means of reducing false positive rates and enhancing data reliability remains only a promising possibility, hindered by the lack of enough ground truth benchmark datasets and the respective testing and evaluation protocols.

> "Important to be able to stop what does not work. Re-siloing academia from practice must be avoided."
>
> **Alex Nikulin, University of Binghamton, New York**

DETECTION AND DISCRIMINATION TARGETS

The discrimination of explosive ordnance from metal clutter remains a key challenge hindering greater efficiency, particularly in clearance. While dual sensor metal detectors and ground-penetrating radar (GPR) systems can reduce false positive rates down to 16–1, in specific contexts, such results vary greatly, remaining extremely high in many other cases, as disclosed by The HALO Trust.

All systems proven reliable to date have been focused on detection of the physical properties of explosive ordnance, but not explosive substances themselves. The Italian National Agency for New Technologies, Energy and Sustainable Economic Development showcased how technologies for detection of bulk and trace explosives have advanced significantly in recent years.

Moreover, bulk explosives detection technologies such as magnetic resonance and neutron/gamma ray detection are reaching fieldable technology readiness levels. Field trials of a magnetic resonance system in Angola, conducted by The HALO Trust, demonstrated a reliable detection capacity for RDX-based plastic-case antipersonnel mines, up to a depth of 12 cm. Furthermore, the systems proved to be simple and easy to operate. Experimental trials of neutron/gamma detection systems from Gamma Reality Inc., which combine 3D mapping and AI-assisted data fusion, have shown the potential for high detection rates coupled with very low false positives, even under wet soil or subject to electromagnetic interference.

While such systems show promise, it is foreseeable they will remain complementary to the wide and efficient use of metal detectors. Therefore, it remains important to continue researching and field-testing advanced systems to improve discrimination methods.

> "Detection rate, false alarm rate are important, but we also need to get to cost effectiveness."
>
> **Mike Zimmer, Minesight**

ROBOTIC MECHANIZATION OF EXCAVATION

During clearance, for every signal confirmed by a detector, an excavation follows. *"The excavation stage is the riskiest part of removing a mine"* (Kateryna Drozd, Demine Ukraine/Ministry of Economy of Ukraine). Manual excavation, conducted by deminers, is still the norm. These amount to millions of excavations every year at the rate of only 15–30 minutes per excavation, and it is where the highest number of deminers' accidents occur. Minimizing the need and number of manual excavations, through mechanization or robotization is the goal, making clearance faster and safer–particularly at the stage where deminers are closest to mines–and enabling new operational capabilities, such as longer daily working hours, The HALO Trust indicated.

Semi-automated off-the-shelf micro excavators, tested in Angola, Ukraine and in Zimbabwe by The HALO Trust, and IOS compressed air excavation systems (robotic platform), have shown promising results. Operational deployment of the latter, in Cambodia, is planned and large trial campaigns in Ukraine are foreseen for 2026. In Angola's Mavinga site, up to 86 per cent of anti-personnel mines are now excavated by micro excavators, while 33,000 mines have been cleared in Zimbabwe, significantly reducing accidents per mines excavated. In Ukraine, the IOS compressed air excavation system showed a potential increase in daily productivity of up to 20 per cent.

However, operational integration remains a key challenge. Adaptation of procedures, terrain conditions and maintenance require careful planning, while steep purchase and maintenance costs remain much higher than for manual tools. Semi-automation of mini excavators combined with improved excavation workflow and UAV tethering would broaden their operational use.

> "Anything that allows me to put a deminer in a hazardous area for less time is super critical–do not stop innovating!"
>
> **Peter Smethers, Fondation Suisse de Déminage**

OPERATIONAL EFFICIENCY AND ENABLING FACTORS

Mine action operations rely as much on enabling conditions as on the tools and methods themselves. Testing, evaluation and accreditation, logistics, information management and data-driven decision-making, together with training and education, are all essential elements of a system that are needed to improve operational efficiency.

MECHANICAL LAND RELEASE: MONITORING EFFICIENCY AND EVALUATING IMPACT

Mechanical assets remain critical tools in mine action, enabling faster and safer technical survey and clearance. Machines are, however, not universally superior; they are suited for specific activities and typically perform best when combined with manual means. This is the case of their application in rubble removal and urban contexts, as presented by the Libyan Mine Action Center (LibMAC). Such an impact is however dependent on context, terrain, and the availability of supporting systems. Whether using tillers, flails, heavy duty or mini excavators, sifting buckets, crushers, racks and others, effectiveness and efficiency depend on the selection of the right tool in the right place, supported by responsive logistics and skilled operators.

A crucial enabling element is the testing, evaluation and accreditation of procedures for such a wide variety of mechanical tools and respective contexts. While the IMAS provide cross-cutting guidance for test and evaluation of mine action equipment, field applications are not possible without considering each specific site. This requires close collaboration of operators and national mine action authorities, to develop, test and document the site-specific procedures to safely and effectively use concrete assets, according to The HALO Trust and the LibMAC.

> "Testing, evaluation and accreditation of machines requires going to the sites, looking at the problems together, and finding the specific solutions."
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> **Michael Nevard, The HALO Trust**

On the other hand, such specific use cases and high operational costs can make machines inefficient investments in contexts where their use is time- or geography-bound. Renting service models presented by DOK-ING or GCS provide an innovative business model approach to machine deployment, maximizing efficient use of each machine as well as creating conditions for the machine to be deployed where it is most needed.

If machines can improve efficiency of operations, their environmental footprint must also be recognized. The use of tillers and flails in agricultural land can deplete soil organic matter critical to fertility and long-term recovery, as the Food and Agriculture Organization of the United Nations has found in recent studies. Integrating agronomic expertise in the planning of operations has ensured new ways of mitigating such impacts. Avoiding bare soils, promoting rapid recultivation with green cover, retaining residues, and supporting farmers with technical and financial assistance, help stabilize and restore the topsoil disturbed by machinery. This ensures that released land can be safely, productively, and sustainably restored to use.

LOGISTICS AS A STRATEGIC ENABLER

> "Mine action without logistics is just a group of very brave people stuck at a checkpoint, waiting for fuel, spare parts, and the one form that never got stamped."

Peter Smethers, Fondation Suisse de Déminage

Another key enabler for the deployment of machines is logistics. In Ukraine, the large-scale deployment of machines by the State Emergency Service of Ukraine has highlighted persistent challenges. The variety of machine types with different logistical needs demand capable deployment planning. The establishment of local machine assembly, spare parts production, and maintenance hubs has shown to reduce operational downtime. However, the availability of means of transport to move heavy machines between sites remains a hindrance to operational efficiency.

Logistical challenges go well beyond the operational sustainability of machines. Import and customs clearance of mine action equipment are often critical bottlenecks as well. In the experience of Fondation Suisse de Déminage, for example, importing an off-the-shelf UAV and sensor systems can take up to two to three years. Each country will be a different case. Pre-positioning stockpiles, establishing framework agreements with local suppliers, and understanding local market constraints are essential to ensure equipment reliability and timely operational support.

Another recurrent challenge is access to and regulations on explosives, which are the main means of disposal of explosive ordnance. Innovative, context-specific approaches are emerging to overcome such logistical barriers, including Golden West's non-explosive destruction system and explosive harvesting programme, which have already been used in Cambodia for some time, as well as MuniRem Environmental's green remediation technologies for explosives.

Furthermore, while the equipment logistics are important, health and safety of personnel is paramount. Providing key services such as housing, water, power, connectivity, waste disposal in field operations, and the respective environmental considerations, can represent up to 40 per cent of the cost of operations.[1] Digitalization, including fleet management systems, planning and monitoring tools are needed to support operational efficiency.

1 Operational Efficiency in Mine Action - GICHD

DATA-DRIVEN DECISION-MAKING: OPERATIONAL ANALYSIS AND INFORMATION MANAGEMENT

Digital and data-driven planning tools come up as a cross-cutting theme concerning operational efficiency, whether for planning and semi-automation of machine deployment, UAV-based sensor detection, logistics planning, or for prioritizing, tasking, and monitoring operations effectively. Data-driven approaches will transform mine action, pushing for shifts on the management of data and information.

Technology in this field has made strides in recent years. Cloud-based geographic information systems and AI-enabled tools, such as those deployed by ESRI's toolbox, allow retrieval of information and tool creation without extensive technical skills, enabling automation, deeper analysis, and easier, more accessible interaction with existing datasets. This unlocks an immense potential for relevant operational analysis capacities.

National mine action authorities are taking this on board along with their implementation of information management systems. The Somali Explosives Management Authority described Somalia's ambition to leverage the implementation of the Information Management System for Mine Action (IMSMA) Core as a national mine action database, to explore data analytics, hazard mapping, and enhance prioritization. But key challenges are also underlined, as successful digital transformation in mine action depends as much on people, internal standards, and processes, as on technology.

> "A successful transition [to data-driven decision making] requires a holistic approach that addresses not only technology but also people and processes."
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> **Abdulkadir Ibrahim Mohamed, Somali Explosives Management Authority (SEMA)**

In other words, technical performance alone does not guarantee organizational impact, as Mines Advisory Group International explains, based on initial research measuring the correlation between digital adoption and real, strategic value–oriented, efficient, data-driven decision-making.

Building and adopting digital tools that align with operational needs, are sustainable and deliver impact requires further development of capacities, training and education as well as senior management ownership. This underscores that further professionalization of the sector is still needed.

ADVANCING PROFESSIONALIZATION

Investing in the training and education of the people working in mine action is key to underpinning operational efficiency, as indicated on multiple occasions at the conference. It is also crucial to enhance credibility, to capture and retain talent, and for career mobility. The latter is also important for the transition of personnel to the labour markets upon completion of national programmes.

Partnerships with academic institutions create pathways for certification, accreditation, and career progression at different levels. One example is The HALO Trust and the Glasgow Caledonian University, integrating explosive ordnance disposal technical training into credit-rating frameworks, and providing recognition equivalent to a bachelor's degree. Also, the Lebanese Mine Action Center and the Lebanese American University combine operational experience and academic rigour to deliver a range of courses for senior professionals. The National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" provides formal degree programmes and short-term certifications to prepare engineers and veterans to operate in EO-affected environments, linking technical expertise with environmental and humanitarian objectives.

Nonetheless, challenges remain, including different training packages for different national contexts, and the lack of a global academic framework and the resources needed. Even if the IMAS has made strides in defining minimum proficiency requirements for many staff profiles, no global accreditation mechanism provides validation of IMAS alignment, which is a critical shortcoming to be addressed in the pursuit of greater operational efficiency.

AMMUNITION MANAGEMENT

SAFEGUARDING THE SUPPLY CHAIN

Ammunition supply chains remain fragile in many regions affected by conflict or in states with limited capacities. Gaps in safety, security, and traceability expose communities to unnecessary risks. The call for technological solutions by the UN General Assembly Global Framework for Through-life Conventional Ammunition Management highlights the urgent need for scalable digital tools across the ammunition life cycle. These include inventory management, risk assessment and diversion detection, automated tagging, AI-driven analytics, block-chain backed tracing and supply-chain management, enabling secure, multinational collaboration.

A wide range of digital technologies are already being analysed and explored in the field of small arms and light weapons (SALW), as the United Nations Institute for Disarmament Research (UNIDIR) and Small Arms Survey were able to show. This includes AI-assisted scraping of large online open-source data and big data analytics, chemical encoding, electronic seals, radio-frequency identification (RFID) and AI-assisted computer vision. These technologies are mature and available in multiple fields of application, holding the potential for wider use in preventing, detecting, and countering diversion, both of SALW and conventional ammunition.

On the other hand, both UNIDIR and Small Arms Survey emphasized that adapting solutions to concrete operational needs is key, and in many cases, *"a fully tech approach may miss the specific needs and the context of implementation, and as such, the first steps may not be tech-based but rather focused on understanding the issues at hand and the context."* (Hardy Giezendanner, UNIDIR). Refining existing processes can also yield significant improvements. Consistent marking practices, combined with data-sharing frameworks, strengthen traceability and allow states to implement international standards.

The civil commercial explosives sector is another industry dealing with similar challenges, facing concrete requirements in terms of track-and-trace of explosives from production and storage, to transport and application. ORICA Mining Services Portugal explained that in the case of the European Union, the existing regulations are clear and extremely strict, demanding that each unit product must be uniquely marked and identified with a QR code, with packages having aggregated QR codes, from the box to the pallet level. National authorities responsible for monitoring have full access to the stock listings, control points, and transfer of responsibility.

Further discussion highlighted that, in the civil commercial explosives sector, the debate on marking and tracing is primarily regulatory and legal in nature, rather than a technological or logistical challenge. Legislation making such systems mandatory, with set requirements and clear monitoring, control roles, and responsibilities, has driven the development of the necessary technological solutions, which were subsequently widely adopted.

However, for conventional ammunition, the challenges may still lie in the technological domain, particularly in conflict-affected settings. Having to deal with sensitive ammunition stockpiles data, digital solutions, no matter how efficient and effective, demand high levels of security at national level, amid fears that multinational collaboration and data- sharing frameworks may allow critical breaches of the digital systems. The DFINITY Foundation introduced sovereign cloud platforms for secure, resilient, and decentralized applications. Sovereign clouds are designed to minimize dependence on any single foreign legal jurisdiction by embedding governance and security controls at the design level, supported by distributed systems and AI-enabled secure network protocols. Such systems can reduce trust requirements among institutions and enable the sharing of ammunition supply chain data across borders without compromising security.

While the remaining challenges are wide-ranging, advancing the implementation of the UN General Assembly Global Framework for Through-life Conventional Ammunition Management, requires a more systematic approach to enable innovation in ammunition management–through the collaborative identification of concrete problem statements and their respective contexts, as well as mapping technology maturity, building on existing efforts and initiatives.

ADDRESSING UNDERWATER EXPLOSIVE ORDNANCE

Underwater explosive ordnance contamination presents significant operational, environmental, and regulatory challenges. As maritime infrastructure expands and access to seas and inland waterways becomes increasingly vital for post-conflict recovery, both legacy contamination and new hazards from recent conflicts–such as in Syria, Ukraine, and Yemen–carry far-reaching consequences. Their humanitarian, economic, and environmental impacts outpace existing policies, regulations, and capabilities. Despite technological progress, practical civilian and humanitarian responses remain limited, leaving a persistent gap between what is technically possible and what can be implemented in practice.

Such a gap is demonstrated by the experience of Humanity & Inclusion and HAMAP-Humanitaire in Northeast Syria, where the absence of hyperbaric facilities and certified dive teams has triggered the adoption of innovative approaches to the health and safety of divers trained locally. Despite such challenges, this work has enabled the rehabilitation of critical infrastructure such as bridges, water reservoirs, and canals. Similar challenges are highlighted by the State Transport Special Service in Ukraine, extending to the lack of national standards or normalized equipment or procedures for underwater survey and clearance.

Good practice from current initiatives, such as the research and technology efforts led by the GEOMAR Helmholtz Centre for Ocean Research Kiel, the Danube shipwreck removal operations of the Serbian Mine Action Center or by commercial operators such as TetraTech, indicate advances in a wide spectrum of technical fields. These range from multi-criteria prioritization methods, and risk and quality management, to autonomous underwater vehicles, sensing systems, bioremediation, and offshore disposal platforms.

The recent attention and resources allocated to the subject among European countries and the United Nations, highlighted by JPI Oceans, while focused on security of the seas and environmental conservation of the oceans, hold an opportunity to explore new policy paths leading to the mobilization of the resources needed to further address the challenges of underwater explosive ordnance.

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