FIELD TRIALS OF THE SMART SYSTEM AND TECHNICAL SURVEY DOGS IN CAMBODIA

FINAL REPORT

Field Trials of the SMART System and Technical Survey Dogs in Cambodia – Final Report, GICHD, December 2021

This project was managed by Stanislav Damjanovic, GICHD. Implementation of project activities in the field were under the responsibility of Michael Heiman, APOPO, with the support of the Cambodian Mine Action Centre (CMAC). Realisation of the project was financially supported by the City of Geneva / Ville de Genève and publication was made possible thanks to the financial support of the government of Switzerland.

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1. FOREWORD

In the mine action sector, it is widely recognised that one of the essential conditions for increasing effectiveness is to release explosive ordnance-contaminated land through appropriate low-cost survey methods, where possible, rather than through very expensive mine clearance methods, as is too often the case. The basic principles of land release are generally accepted, but effective and reliable implementation in the field is complex. An effective technical survey tool is one that can be applied in most areas, regardless of the difficulties caused by the terrain and vegetation. Animals have good potential for technical investigation, but their use is still linked in many cases to the prior use of expensive machinery (brush cutters) and restriction of movement, due to leashes during this type of operation, which present considerable limitations in deployment and higher operating costs. The idea of developing a supporting system that would allow specially-trained dogs to go more 'freely' into hazardous areas led to the development of the SMART (Swiss Mine Action Reduction Tool) system, with the objective of increasing the efficiency of technical survey (TS) operations, without compromising safety. An innovative concept has been developed to use dogs to boost TS. The concept is based on the creation of the SMART kit, an intelligent backpack for remote guidance and observation. The system is positioned on the dog's back and allows the animal to increase its effectiveness in the identification of mines and cluster munition remnants.

The SMART project was initiated in 2016 by World Without Mines, Digger DTR and the GICHD, however the origins of this idea can be traced back to some initial concepts that were being considered by Norwegian People's Aid (NPA) in 2014. After initial trials in Bosnia and Herzegovina, and Cambodia by NPA, improvements to the initial system were made and it became evident that the system could reach the intended objectives in a test environment. What remained unclear was how this system would perform during real-life operations in the field. Therefore, in 2019, with the support of the from Ville de Genève (City of Geneva), the GICHD decided to conduct field trials through its partner APOPO – an organisation focused on the use of animal detection systems (ADS) and with significant ADS field experience. The project was further supported by the Cambodian Mine Action Centre (CMAC), whilst technical support and system maintenance was provided by Digger DTR, the manufacturer of the system.

The aim of the project described in this report was to document and test an innovative technical survey methodology operationally, complementing the existing traditional approach. This innovation involved specially trained long-range search dogs, able to penetrate a variety of terrain and vegetation, and equipped with an intelligent harness. As this had never been used before in mine action, this innovative approach required several years of technological and operational investigation and is now finally ready for wider use.

The SMART system is an intelligent harness allowing remote tracking, guidance and observation. Positioned on the dog's back, the SMART kit increases the effectiveness and autonomy of the dog for the identification of landmines, cluster munitions and other explosive remnants of war. The SMART kit allows dogs to be used much more efficiently during technical survey.

All TS methodologies should provide a very high level of confidence that all hazardous items present are indicated. This pilot was the first time ADS were used and evaluated in vegetated areas without prior vegetation cutting, making it particularly important that all items were found. All areas surveyed by the technical survey dogs were therefore subsequently checked by manual teams using metal detectors.

2. MANAGEMENT SUMMARY

The aim of this project was to validate the Swiss Mine Action Reduction Tool (SMART) technical survey dog (TSD) technology and methodology for technical survey (TS) and cluster munition remnant survey in Cambodia. During the project, the TSD team surveyed 2,227,100 m^2 of suspected hazardous area and detected 262 mines, cluster munition remnants and other explosive remnants of war (ERW). The project began in July 2019 and ended in December 2020; a total of 18 months.

The concept of dogs sniffing out landmines in vegetated areas has been historically questioned, because of the perceived limited manoeuvrability of dogs and the related consistency of their search patterns. However, this project has shown that if the dogs are trained to manoeuvre and penetrate vegetation, odour detection becomes even less challenging, because the odour is contained in the vegetation and is widely spread on top of the surface.

This publication explores various aspects of SMART TSD technology and its methodology, through data collected during the project in Cambodia. Based on this data, APOPO concluded that the TSDs provide a significant cost efficiency improvement, compared to other TS methods used today in Cambodia and globally. However, there is a need for programmes to consider their specific contexts, taking into account the start-up costs that are required – especially in those programmes that do not already have dogs included in their operations.

The first phase of the project included systematic TS in mine-affected areas in Preah Vihear province, Cambodia. The operation took place in Choam Khsant district, along the border with Thailand. The mines and ERW in this area are remnants of the internal conflicts which took place in 1975–1998, with mines laid by the Khmer Rouge, government forces and Vietnamese occupation forces. The 2011 border clash between Thailand and Cambodia created additional contamination from cluster munitions.

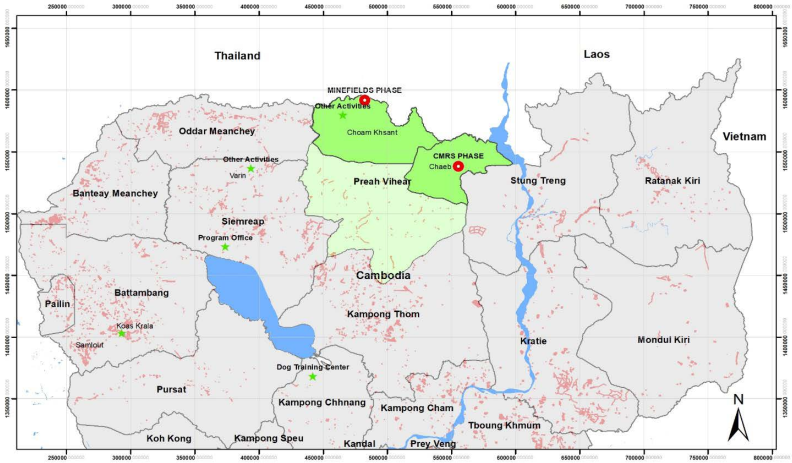


Figure 1 – Project Location

The second phase of the project was conducted in a cluster munitions-contaminated area in Chaeb district in the eastern part of the province. In the 60's and 70's, one of the Communist supply routes passed through this district and continued to the east, eventually connecting to the Ho Chi Minh Trail and South Vietnam. As a result, the road that crossed the district from west to east heading towards the Mekong River, was severely bombed by United States forces during the Vietnam War, leaving thousands of unexploded cluster munitions behind.

The project consisted of a six-person team with four technical survey dogs equipped with SMART kits. Manual detection capacity entailed carrying out full manual checks once the dogs had performed their search, to validate the reliability of their detection work.

The project was managed by the GICHD and implemented by APOPO, in partnership with the Cambodian Mine Action Centre. APOPO's dog training centre in Cambodia provided technical assistance and monitored the performance of the dogs throughout the project.

3. SYSTEM COMPONENTS

3.1. TECHNICAL SURVEY DOGS

3.1.1. DOG SELECTION AND TRAINING

Technical survey dogs (TSDs) are highly motivated search dogs that go through a rigorous selection and training process and show consistent ability to follow a long search pattern of at least 25 metres while positively indicating buried explosive ordnance (EO) items in vegetated areas. Traditional long leash mine detection dogs (MDDs) are normally trained to follow a shorter search pattern of 10 metres, in areas that have gone through prior ground preparation, allowing the dog to manoeuvre freely. Statistically, when training a group of search dogs to detect EO on a long leash search pattern, very few (if any dogs) will have the ability to search in vegetation and consistently follow a longer search pattern.

To maximise the chances of identifying a group of 8,10 or 12 search dogs that could be TSDs, APOPO had to recruit highly skilled and experienced personnel to scout for dogs in several breeding facilities across Europe. The first eight TSDs that passed the training and became operational in Cambodia and South Sudan in 2019–2020, were part of a group of 12 dogs that were scouted and recruited from different sources in Europe in 2018. The dogs were brought to Cambodia, trained as long leash MDDs and then went through an additional six-month TSD training. The additional TSD training included gradual introduction to vegetation and obstacles, and long- range dog control techniques with and without a leash – techniques not used with traditional MDDs. During this training period, only eight of the 12 were chosen to be accredited as TSDs, while the other four could not meet the TSD criteria and were eventually accredited as long leash MDDs instead. Four TSDs were selected for this project and the other four were prepared and dispatched to South Sudan.

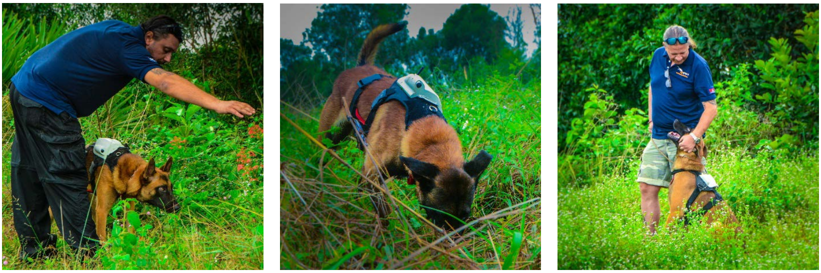


Figure 2 – Training TSDs in Cambodia

Training TSDs requires a large training area, built to simulate the operational environment used for technical survey – areas with natural vegetation and large amounts of buried EO. Alongside this training area, there should be a separate part with a traditional boxing system containing buried EO, where specific techniques can be practiced. APOPO built a 2.5 km-long TSD training area in Cambodia, in partnership with the Cambodian Mine Action Centre, with 300+ targets in 100 training / accreditation lanes.

Figure 3 – Structure of TSD training areas

The four dogs that participated in the project in Cambodia are listed in the table below.

DOG NAME	BREED	GENDER	DATE OF BIRTH
CIKLON	Malinois	Male	28/05/2016
TURBO	Malinois	Male	06/03/2016
MANNES	Malinois	Male	20/04/2017
GIZMO	Malinois	Female	27/04/2016

3.2. THE SMART SYSTEM

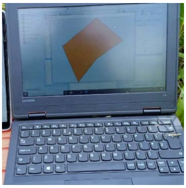
The TSDs are equipped with the Swiss Mine Action Reduction Tool (SMART) system. In practical terms, the SMART system for mine detection dogs is an electronic device integrated in a dog harness. Thanks to the audio system and Global Positioning System (GPS), the dog handler can give voice commands to the dog using Voice over Internet Protocol technology at up to 100 metres (medium-dense vegetation). On an Android smartphone, the dog handler can view the map with the dog's position and the live video feed from the harness camera in real time. However, there was no need for video camera or voice command functionality during the trials in Cambodia. The WiFi transmitter integrated in the system creates a WiFi 'hotspot' allowing communication and data exchange between the computer and the smartphone. Statistics such as area covered, area remaining to be covered, dog position, GPS coordinates of alerts, and video are all recorded and collected in a consolidated database. Once the dog's work is completed, a report compatible with the Information Management System for Mine Action (IMSMA) can be generated easily, and maps can be exported by the software in standard geographic information system formats (kml and shapefiles). The IMSMA database is a management tool aimed at providing correct, consolidated, and appropriate information to decision makers and mine action actors. This decision support system was developed by the GICHD and helps in the planning of operations by collecting information from all those involved in land release. However, the SMART can be modified and integrated to work with some other information systems if needed. The effectiveness of the SMART system thus lies in this systematic integration of the recorded data in a monitoring system providing precise information for further investigation. A SMART set is delivered in three very resistant cases which contain:

- 2 x harnesses equipped with the SMART system;
- 4 x harness accumulators;
- 2 x Android smartphones;
- 2 x earbuds;
- 1 x Lenovo laptop which acts as a server;
- 1 x WiFi access point;
- 2 x accumulators for WiFi access points;
- 1 x WiFi antenna;
- 2 x user manuals.

The system went through several tests and trials and its final version was released in 2016. During 2016–2017 there were several attempts in the mine action sector to put the system into operational use. At that time system components were relatively unstable, and the level of complexity high, making it difficult to use on a steady basis. In 2017, after the first trials were done at the Norwegian People's Aid Global Training Centre in Bosnia and Herzegovina, the first technical challenges occurred. It was noted that there were some issues with the accuracy of the existing GPS antenna and these problems were addressed immediately. Digger exchanged the 'flat' antennas with 'cylindrical' HELIX antennas, after extensive testing. Although this was somewhat of a surprise, it was to be expected that the field trials would identify some of the potential issues, which, ultimately, was the goal of conducting the trials in the first place, before deploying the system in the field.

The first 'heavy' version of the SMART system (left) vs the current look of the system (right), with significant improvements and reduction of the overall weight of the kit

The SMART is a satellite-based track and trace system with four main components: server, mobile telephone, harness and antenna. The antenna provides a 100-metre radius network, which allows communication between the harness, the mobile and the server. The harness is where the GPS is mounted and the server registers and stores operational data. When a handler logs into the mobile app, the operational data is transferred from the server to the app, allowing him / her to see their location and that of the harness. When recording has started, the information is shared live between the system components and stored on the server once the session is closed.



Server

Mobile

Harness

Antenna

In 2017, shortly after APOPO established its dog training programme and centre, the GICHD allocated several kits for APOPO's future use. In 2018 Digger DTR provided training, and six kits were allocated to the dog training centre in Cambodia. APOPO learned how to work with the SMART system and in March 2019 it was used in operations in Cambodia for the first time.

4. VALIDATION

This was the first time that technical survey dogs (TSDs) and the Swiss Mine Action Reduction Tool (SMART) system were used operationally and there were many lessons learned throughout the project, leading to system improvements over time. As a result, the performance and productivity averages are conservative, since they also include the learning and improvement curves that were experienced throughout the duration of the project.

The TSD team was operational during two periods:

- Minefield phase – 24 November 2019 – 31 July 2020
- Cluster munition remnant survey (CMRS) phase – 1 November 2020 – 31 December 2020

Between 1 August and 31 October 2020, the TSD team conducted CMRS training and annual TSD accreditation. In this period the team members also used their annual leave days.

Phase	Start	End	Calendar WD	Team WD	TSD Training days	TSD search WD	Manual search WD[1]	Lost WD
Minefields	24/11/2019	31/07/2020	165	153	20	112	21	12[2]
CMRS	01/11/2020	31/12/2020	35	35	6	29		0
	24/11/2019	**31/12/2020**	**200**	**188**	**26**	**141**	**50**	**12**

1 Workdays (WD) on which the TSD team did not use dogs but worked only with metal detectors. In the CMRS phase, the team always used both methods, first dogs, then metal detectors.

2 Reorganisation due to COVID-19 outbreak.

4.1. MINEFIELDS

4.1.1. GENERAL

The TSD team conducted technical survey in 14 suspected hazardous area (SHA) polygons in Choam Khsant district, Preah Vihear province, covering 1,434,882 m^2 in total. According to the national database, 3 out of 14 polygons were registered as A1(high density anti-personnel (AP) mines) and 11 were registered as A4 (low density sporadically laid AP mines). AP mines were found in 13 out of 14 polygons and a correlation between the initial risk category and the findings was not seen. The TSDs conducted systematic technical survey (TS) in the 14 polygons, covering 50 percent of it in total. The polygons were fully checked by Cambodian Mine Action Centre (CMAC) manual teams following the TSD work, and no additional items were found.

	Class	Minefield serial number	Minefield size in m^2	m^2 recorded on SMART	m^2 after merging between dogs	m^2 after 10% deduction	% of area surveyed	AP mines found	ERW found	Cluster munitions found	Undefined indications
1	A1	10259	61,554	18,969	17,142	15,428	25%	7	1	0	13
2	A1	10275	97,876	51,415	43,081	38,773	40%	23	5	0	3
3	A4	02128	127,852	54,113	49,348	44,413	35%	9	5	0	12
4	A4	02153	110,538	70,658	57,607	51,846	47%	9	5	0	8
5	A4	02148	126,056	87,945	76,205	68,585	54%	8	5	0	8
6	A4	02116	126,502	86,803	76,806	69,125	55%	13	3	0	9
7	A4	02147	128,270	88,252	78,388	70,549	55%	7	5	0	0
8	A4	02149	124,437	85,065	76,775	69,098	56%	6	7	0	3
9	A4	02168	138,187	90,550	79,406	71,465	52%	24	5	0	7
10	A4	12358	50,860	35,005	31,956	28,760	57%	3	3	0	0
11	A1	02174	81,006	53,572	46,493	41,844	52%	15	4	0	3
12	A4	02167	89,973	55,981	50,438	45,394	50%	2	1	2	1
13	A4	02136	43,981	30,934	26,887	24,198	55%	0	4	0	0
14	A4	02166	127,790	95,790	82,348	74,113	58%	24	8	0	10
		Total	**1,434,882**	**905,052**	**792,880**	**713,592**	**50%**	**150**	**61**	**2**	**77**

4.1.2. ITEMS FOUND BY THE TSDs

The TSDs found 150 AP mines, 61 items of unexploded ordnance (UXO) and two cluster munitions. An overview of the items showed that the TSDs successfully indicated not only classic TNT targets, but also mixed compositions, most of which were composed of TNT and RDX.

AP Mines	
USSR PMN AP mine	27
USSR PMN2 AP mine	13
Chinese Type 72A AP mine	11
Chinese Type 69 AP mine	34
Chinese POMZ-2 AP mine	31
Chinese POMZ-2U AP mine	4
Chinese POMZ-2M AP mine	3
Khmer IMP AP mine	27
Total	**150**

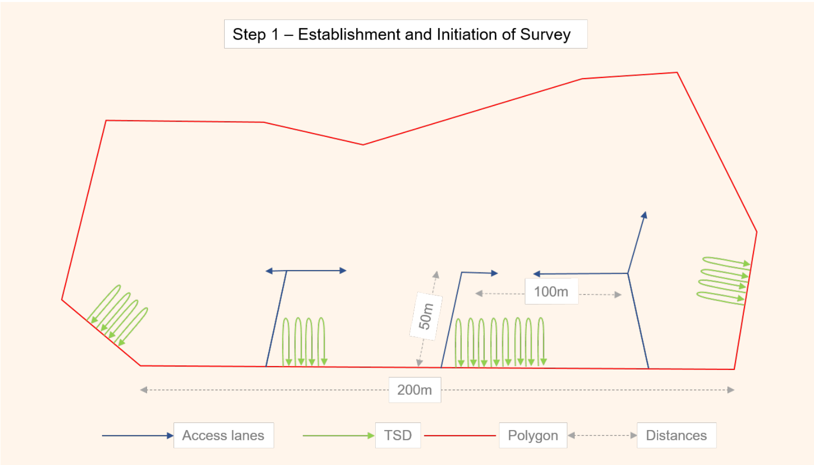
UXO	
Chinese 60 mm type 27 mortar	17
Chinese 82 mm type 30 mortar	11
Chinese 120 mm model 33 mortar	4
Chinese 107 mm type 63 rocket	3
Chinese 75 mm type 52 recoilless.	5
US 81 mm M 374 mortar	1
Chinese 43 mm M 46 hand grenade	7
USSR 85 mm PG7 rocket	4
US 105 mm M1 projectile	1
USSR F1 hand grenade	2
USSR 80 mm PG2 rocket	6
Total	**61**

Cluster munitions	
US M42 DP submunition	2
Total	**2**

4.1.3. SYSTEMATIC TECHNICAL SURVEY WITH TSDs

One of the main activities of the project was developing the methodology and refining the standard operating procedures (SOPs). Systematic TS using the TSD method is conducted according to the following steps:

4.1.3.1. STEP 1 – ESTABLISHMENT AND INITIATION OF SURVEY



After establishing the turning points of the polygon, the team starts creating access lanes into the polygon every 50–100 metres. These lanes are created by using the TSDs in a double search full clearance mode with a long leash or by using metal detectors. TSDs start surveying the polygon from the available safe areas as soon as these become available.

The TSDs search lanes of 25–27 metres in length perpendicular to the safe areas. The width of the boxes / panels is set at 50 metres so the TSDs can cover them fully by working from both sides. The length of each box / panel is defined as a maximum of 100 metres, to allow for better mobility of the team within the polygon.

4.1.3.2. STEP 2 – FULL EXTENSION OF THE SURVEY

The team tries to create access lanes that will allow them to survey every point in the polygon. During this stage, the team also identifies areas with obstacles, such as dense bamboo, sharp vegetation, and river streams. These areas are excluded from the TSD survey plan and are surveyed manually. The direction of the access lanes is adapted to the ground conditions and should eventually allow for a maximum area to be covered by the TSDs.

The TSDs systematically search perpendicular lanes of about 25–27 metres, running from the access lane into the uncleared area. The handler decides how far he needs to move along the safe area before establishing the next search lane. This depends on multiple factors such as consistency of the dog search on the way back, deviation due to obstacles, and observed changes in behaviour, but is at most three metres.

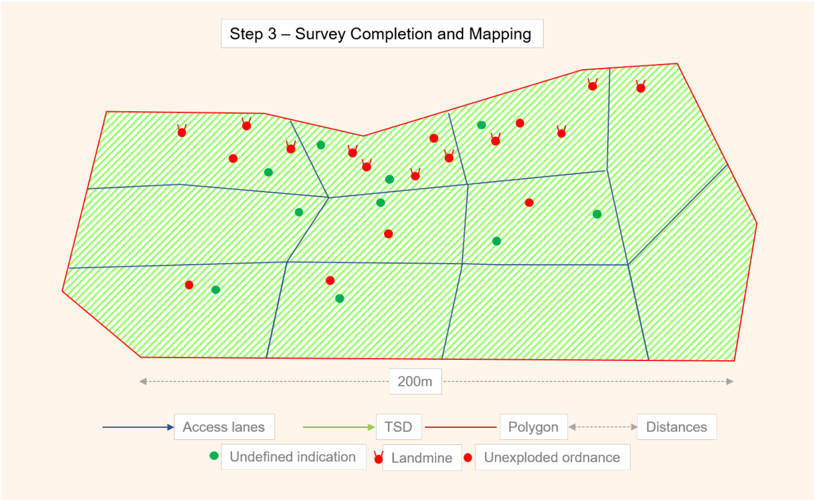
When the dog indicates, the handler marks the alarm on the SMART and measures the distance using a 30-metre leash. Handlers cannot access the location of the indication at this stage. During the work in the first four polygons of the project, the handlers marked the indication with a special picket on the access lane, writing the distance on a plastic placard.

This method created several challenges, especially when the indication was beyond 20 metres in dense vegetation. Since the handlers investigated the indications during the afternoon, they spent a lot of time identifying the exact location where the dog had been when it indicated, and thus it became very difficult to measure the distance between the location of the indication and where the item was actually found.

Figure 4 – Indication picket and placard on access lane

Therefore, APOPO developed the beacon dropper system after finishing the fourth polygon, which was used for the first time in the seventh polygon. The device, attached to the dog's collar, allows the handler to press a button and release a beacon, which can subsequently be found quickly by the investigating person because of a beeping sound which it emits once activated.

4.1.3.3. STEP 3 – SURVEY COMPLETION AND MAPPING



When the survey is completed, the data from the SMART is exported to shapefiles and the survey map is created using ArcMap. The SMART data goes through a refinement process, such as merging, cutting out tracks outside the polygon and reducing the tracks made on the access lanes. The result is a complete survey map that includes dog tracks, items found, undefined indications, and the percentage of survey coverage.

Based on the map, the supervisor in charge decides which areas will be designated as confirmed hazardous areas (CHAs) and will have full manual clearance; which areas can be reduced; and what level of quality control they will conduct. The supervisor can also require additional survey in specific areas prior to making any decisions. APOPO has built decision-making algorithms into its SOPs, but this is a very context- and country-specific issue that should be defined by the operator for each specific country and task.

4.1.3.4. EXAMPLE

The following map (Fig. 5) was made after the survey in polygon number 7 – 02147. The size of the SHA was 128,270 m². The TSD team completed the survey in 12 days and systematically covered 70,549 m² – 55 percent of the area. There were two kinds of obstacles for the search: a river stream crossing the polygon from north-east to south-west and several sharp bamboo pockets in the southern part of the polygon. The dogs found seven AP mines and five items of UXO. Following the survey, the areas shaded red (46 percent) were marked as CHA and the remaining areas (54 percent) were reduced. Due to the project objectives, the whole area was checked by metal detectors and no additional items were found.

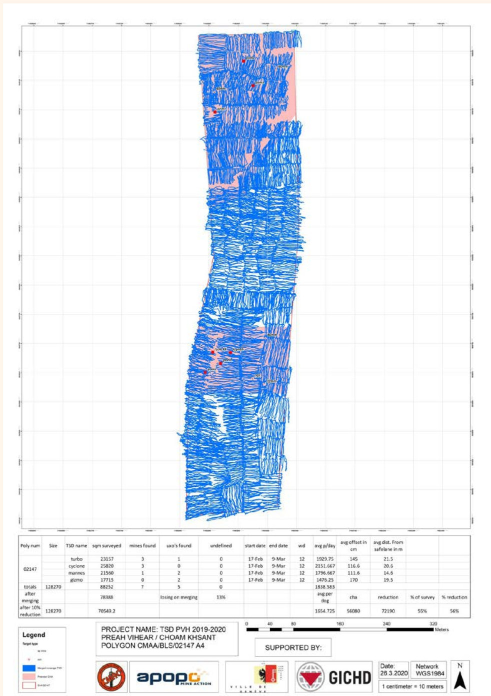


Figure 5 – Survey map 02147

4.1.4. METHODOLOGY KEY POINTS

4.1.4.1. VEGETATION

Vegetation has historically been treated as an obstacle that seriously affects an animal's ability to manoeuvre and makes the handler's control and observation process much harder. This project was the first time that animals were authorised to work without prior vegetation cutting in Cambodia, since data was first recorded.

Figure 6 – TSD indicates in vegetated area

The main challenge for being able to search through vegetation is to identify the animals that are inherently able to perform such a task and to train them. From the moment they are identified and trained, the detection process itself becomes easier since the odour of TNT in vegetation tends to be stronger than if the vegetation were cut. The main lessons learned from working in vegetation are:

- The scent plume is wider and therefore the investigation perimeter of the indication should start with 3 x 3 metres and continue to 6 x 6 metres, even if the target is located.
- Bamboo and other sharp vegetation should be avoided, to prevent unnecessary injury to the dog.
- When the vegetation is very dense, there is a higher chance that the 30-metre leash will get stuck on the dog's way back. In this situation, the handler should remove the leash and work without it. Leashes should be made of hard plastic material, so that they can glide through the bush.

4.1.4.2. WORKING RANGE

The optimal working range of a single TSD was set at 25–27 metres because dog`s behaviour is within a control zone; the handler can see the dog in most situations; the dog can, generally, make straight search patterns; and there is quick access to indications. The project was started with the ambition of deploying the dogs as deeply as possible – up to a range of 50 metres. During the work in the first polygon, the following challenges were observed:

- After searching approximately 25–30 metres, the dogs tend to deviate from their course. Since it's systematic TS, the lines need to be as straight as possible and cover the area as evenly as possible.
- Not all the dogs on all occasions could penetrate up to 50 metres. This breaks the continuity of the systematic survey and creates pockets that have not been surveyed and which need to be accessed from different angles.
- Opening an access lane for dog indications of 40–50 metres from the handler becomes a very time-consuming task.
- Leash weight at 50 metres in length is high and it takes time to roll it up after every session, plus it tends to get caught in the vegetation.

It was therefore decided to set a working range standard that can be met by all dogs on all occasions, that saves time on investigating further indications and allows continuity of systematic TS. The maximum range was set to 27 metres which was used throughout the remainder of the project. A minimum deployment range of 25 metres was decided on and if the dog did not reach it, the handler sent the dog again from a slightly different angle.

The width of the dog search was set to one metre (50 cm either side of the dog) in the SMART system. Although dogs were indicating from a greater distance, the search width was not changed because the dogs were only accredited for a one-metre width.

4.1.4.3. ON LEASH AND OFF LEASH

When the TSD concept was initially developed, the ambition was to use the TSD almost exclusively off leash. Off leash searches can make sense in cases of targeted TS, when the required level of coverage is lower than 50 percent and the idea is to identify a threat in a specific area within the polygon (such as former military positions). In this project, the team was conducting systematic TS with specific coverage targets. Therefore, the surveyed lanes needed to be as straight and as systematic as possible. Off-leash dogs that are sent on a 50-metre distance will likely deviate after 25–30 metres on their way forward and back, which will create unequal coverage of lanes and unnecessary overlapping that will not be counted as square metres searched. In addition, not all dogs behave the same when sent long range off leash. Since the system should be scalable, requirements were set within a range that most TSDs could reach. Throughout the project the TSDs therefore worked within a 25–27-metre range, alternating on and off leash based upon the handler's interpretation of the situation.

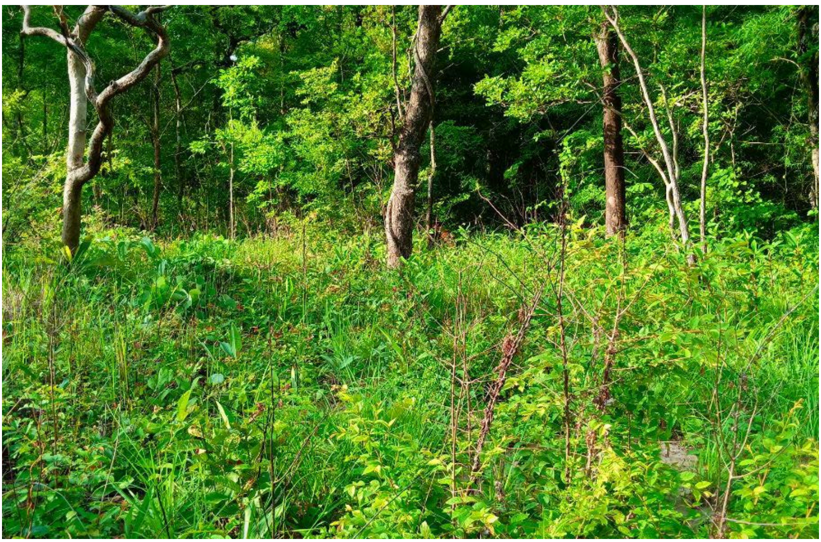


Figure 7 – TSD indicating on a 25-metre range

4.1.4.4. DIVISION OF DAILY SCHEDULE

The TSD team's working day is divided into two parts – 6:00–10:00 and 10:00– 14:00. In the morning the team is focused on work with the dog, when the weather is cooler, and the dogs can reach their maximum productivity. The dogs are required to deal with vegetation and other obstacles and they therefore get tired after 3–3.5 hours of continuous work. When the work with the dog is finished, the team moves to the second part, creating access lanes for the following day and investigating all the indications made by the dogs earlier that morning.

Cambodia has a tropical climate and working hours for the dogs are limited. In countries where the weather allows dogs to work throughout the whole day, it is preferable to match two TSDs to each handler, allowing the TSD work to last 6–7 hours instead of 3.5 hours. In this situation, additional manual capacity would be needed to create the access lanes and investigate dog indications, since the handlers would be busy working with the TSDs throughout the whole of the day.

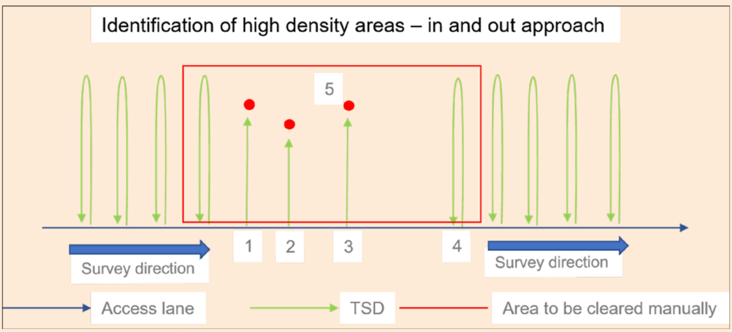
4.1.4.5. ACCESS LANES

To ensure maximum productivity of each TSD, the team should always plan at least one day ahead and prepare a sufficient number of access lanes where the TSD will be deployed. For example, if one TSD searches 1,673 m^2 per day, covering 50 percent of the area, it means that 3,346 m^2 need to be accessible. To check 25-metre search lanes in a 3,346 m^2 large area, 133-metre-long access lanes are needed. The lane should be three metres wide, and therefore 399 m^2 of area needs to be prepared in advance. To save time and effort, an access lane should be created in a place where two TSD teams can use it, working from both sides.

Figure 8 – Two TSDs working at the same time from an access lane

High Density In and out approach

One of the techniques developed during the project was a method to tackle high density pockets. Animals have known limitations in such areas, so an approach was chosen where TSDs were used to define the boundaries of such pockets. This was done with an 'in and out' approach as illustrated below.



The team surveys the area from left to right. For example, in lane 1 the dog indicates. The handler marks it, drops the beacon and continues surveying. In lane 2, the dog indicates again. The handler now moves five metres along the access lane to create lane 3 and deploys the dog again. If the dog indicates again in lane 3, the handler moves 10 metres along the access lane and sends the dog again, creating lane 4. If there are no indications in lane 4, the survey continues as usual. The left boundary of the high-density area is defined by the first lane with an indication and the right boundary by the first lane without an indication. What is left must be cleared manually.

4.1.5. INDICATIONS

As previously mentioned, measuring the distance between the dog indication and the location of the target was identified as a challenge that led to the development of the beacon dropper. The beacon dropper was first used in polygon number 7 – 02147. In addition, it was decided to start collecting data on the distance between the handler and the dog when the dog indicated. This validated the fact that TSDs continued to search when they were far from the handler, including when they were out of sight.

	Minefield serial number	TSD Working days	WD without TSD	AVG productivity p/dog after 10% reduction	% lost on merging	AVG distance from indication	AVG distance of indication from handler	% of area reduced
1	10259	10	2	854	11%	130	N/A	72%
2	10275	24	1	1,102	19%	147	N/A	40%
3	02128	20	1	1,218	10%	124	N/A	32%
4	02153	19	2	1,278	23%	140	N/A	68%
5	02148	15	2	1,362	15%	152	N/A	49%
6	02116	12	2	1,628	13%	162	N/A	51%
7	02147	12	2	1,655	13%	136	19.1	56%

	Minefield serial number	TSD Working days	WD without TSD	AVG productivity p/dog after 10% reduction	% lost on merging	AVG distance from indication	AVG distance of indication from handler	% of area reduced
8	02149	11	2	1,740	11%	116	15.9	48%
9	02168	12	2	1,698	14%	117	12.5	10%
10	12358	5	2	1,575	10%	111	15.8	62%
11	02174	7	2	1,722	15%	96	17.4	70%
12	02167	6	2	2,099	11%	140	23.3	82%
13	02136	2	1	3,480	15%	67	18.8	100%
14	02166	11	2	2,011	16%	125	16.6	0%
	Total	**166**	**25**	**1,673**	**14%**	**126**	**17**	**47%**

The number of indications without any targets found was 77, out of 279 total indications in the minefield phase: 27.5 percent. This is an acceptable range that doesn't require any additional capacity outside the team. These indications were called 'undefined', since there might have been an explosive substance that caused them to indicate but did not contain any metal and therefore couldn't be verified with a metal detector.

4.1.5.1. DISTANCE BETWEEN DOG INDICATION AND THE LOCATION OF THE ITEM

The average distance recorded from the target stands at 126 cm. The data collected without the beacon dropper is less accurate and stands at 142.5 cm on average. With the beacon dropper the average distance is 113.5 cm.

The average distance of indication from the item was based on a less accurate visual estimate in the first four polygons (average 142.5 cm), and on the precise location of the beacon in the subsequent 10 polygons (average 113.5 cm). In total, the dogs indicated an average of 126 cm away from the mine / explosive remnant of war (ERW). This means that the dogs were picking up the scent of items far beyond 50 cm to each side of them, which is the distance taken as the width of the search lane for the calculation of the area surveyed. Studies[3] have shown that the dispersion of explosives from mines in soil can be identified chemically up to one metre away from the mine. Other studies[4] have shown that vegetation tends to absorb TNT and transport it to the aerial parts of plants, allowing a larger scent plume to develop. This was confirmed by the fact that in polygon 02136, which contained almost no vegetation, the average distance was only 67 cm.

A larger scent plume facilitates detection by animals, which results in indications at a longer distance from the landmine / ERW. This was solved by having the manual investigation start in a 3 x 3-metre box around the indication point and continue to 4 x 4, and finally to expand to 6 x 6. There were several cases where two to three items were located within a 4 x 4-metre perimeter which prompted the teams to adhere to this principle.

4.1.5.2. DISTANCE BETWEEN DOG HANDLER AND DOG THAT IS INDICATING

The average distance between the indicating dog and the handler was 17 metres, which in most polygons is a distance at which the dog is no longer able to see the handler. It is a positive indicator that the dogs continue the search without seeing the handler, because it means they are not as affected by cueing symptoms, which can be a major risk in short-range dog handler work.

3 Hewitt, A. D. et al. (2001). *Field gas chromatography/thermionic detector system for on-site determination of explosives in soils* (Vol. 1, No. 9). US Army Corps of Engineers, Engineer Research and Development Center;
Osterkamp, T. (2019). Letter to the Editor–Search dogs and scent prints. *J Forensic Sci* 65, 1, 345–346, https://doi.org/10.1111/1556-4029.14243.

4 Adamia, G., Ghoghoberidze, M., Graves, D., Khatisashvili, G., Kvesitadze, E., Lomidze, D., Ugrekhelidze, G., & Zaalishvili, G. (2006). Absorption, distribution, and transformation of TNT in higher plants. *Ecotoxicology and Environmental Safety*, 64(2), 136–145, https://doi.org/10.1016/j.ecoenv.2005.05.001;
Vila, M., Lorber-Pascal, S., & Laurent, F. (2007). Fate of RDX and TNT in agronomic plants. *Environmental Pollution*, 148(1), 148–154, https://doi.org/10.1016/j.envpol.2006.10.030;
Panz, K., & Miksch, K. (2012). Phytoremediation of explosives (TNT, RDX, HMX) by wild-type and transgenic plants. *Journal of Environmental Management*, 113, 85–92.

4.1.6. MANUAL FOLLOW-UP AND LEVEL OF CONFIDENCE

One of the main project requirements was to conduct a full manual check of the areas surveyed by TSDs, in order to test the reliability of the tool and the method. The project started with a single CMAC seven-person manual team, but it became clear that a larger capacity was required. A second manual team assisted between November and December 2019 and a third manual team joined the project in April 2020. The manual follow-up clearance was implemented according to CMAC's SOPs.

One of APOPO's internal objectives was to build confidence in the system. This is the main reason why the distances between sessions were set to a maximum of three metres and, based on observation, the handlers observed great caution and normally moved only 1.5 to 2 metres between them. The result was a dense coverage and when no targets were found behind the dogs in the first four polygons, it was decided that the same working standards should be kept throughout the whole project. There was pressure to extend the distances between the sessions to speed up the survey and after seeing that the dogs tended to pick up the odour from a great distance, it seemed that although only one metre is covered using the system, the detection range is in fact wider, which brings the actual coverage rate close to 100%. But in this pilot case reliability was particularly important and it was decided that the one metre range and the 50 percent minimum survey coverage in all polygons should be maintained.

The manual teams worked in parallel to the TSD teams and during the TSD training periods, eventually completing the verification work on 15 February 2021. No mines or items of UXO were found in areas surveyed by the TSDs.

4.1.7. PRODUCTIVITY

The main elements that affected speed were vegetation and terrain. Throughout the work in the minefields, the average daily search consisted of 1,673 m^2 per dog per day, after merging and deduction. It was interesting to see that in polygon 02136, that had almost no vegetation, the average was 3,480 m^2 per day – more than a 100 percent increase. It is uncommon to find terrain with no vegetation in Southeast Asia, but it was a good example of what productivity might be achieved when the TSD is deployed in desert conditions, in settings such as the Middle East or North Africa, for instance. The use of unmanned aerial vehicles prior to deployment can determine the nature of the vegetation and terrain, which can assist in operational planning and estimation of the time required to complete the task. In Cambodia, during yearly planning, it was decided that a daily average of 1,700 m^2 per dog should be considered.

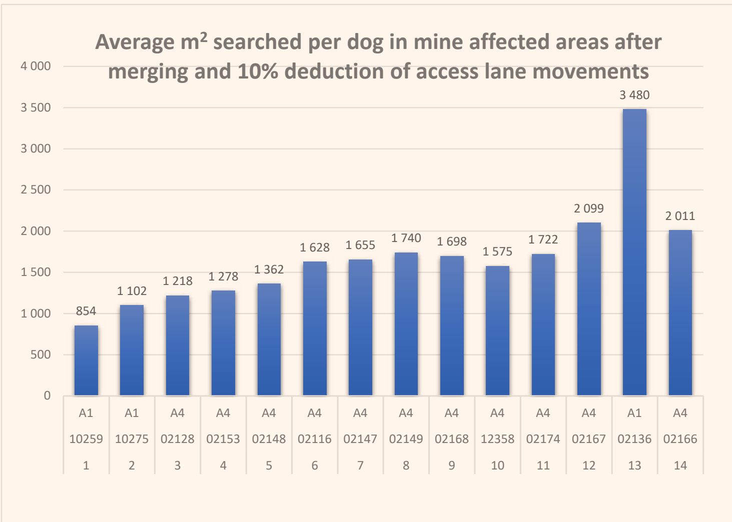


Figure 9 – Average m^2 searched per dog per day

Based on the project data, a TSD team with four dogs in Cambodia can systematically survey 6,692 m^2 of SHA in a single day. With a 50 percent coverage requirement, the size of the area that is surveyed daily stands at 13,384 m^2. In order to survey 13,384 m^2 per day using TSDs it is necessary to work from both sides of the access lane in parallel, and a 270 m^2 linear lane needs to be opened with a width of three metres, or 810 m^2 in total.

The project data also shows that a four-dog TSD team in Cambodia has the capability to survey 13,384 m^2 per day during 10 months in a year in minefield tasks. The average number of dog working days per month is 14, which is equal to 140 dog working days and 1,873,760 m^2 per year (140 days x 13,384 m^2). During a 10-month yearly working period, the rest of the available days can be used for team mobilisation, and opening and closing tasks, for instance. Every year, two months were reduced, due to yearly accreditation and holidays.

It is quite challenging to compare the productivity and cost efficiency of TSDs in surveying SHAs in general. Different organisations and operators have different approaches, most of which rely on manual assets. The only methods with which APOPO could compare productivity are its own methodologies in Cambodia, applied within a similar context. For example, if APOPO used its brush cutter machines, followed up by manual deminers and mine detection rats to survey 1.8 million m^2, it would have cost at least 200 percent more than with the TSD method.

TS TOOL	TSD IN CAMBODIA	MECHANICAL AND MDR IN CAMBODIA
Yearly cost[5]	163,000 USD	169,421 USD
Survey per year	1,873,760 m^2	648,000 m^2
Cost per m^2	0.09	0.26

5 Team cost only, without external management and support.

4.2. CLUSTER MUNITIONS

4.2.1. GENERAL

The TSD team went through additional training to be accredited on cluster munition remnants in October 2020 and operations started on 1 November 2020. The specific cluster munitions training was essential because, in addition to TNT, cluster munitions can contain other compositions, such as Octol, and Cyclotol.

The CMRS phase took place in four SHA polygons in Chaeb district, Preah Vihear province over a total of 792,218 m^2. The common approach in Cambodia is to use existing polygons that were created during a baseline survey and which contain one or more evidence points. The work either started from the evidence point or from the polygon's boundary. The whole of the polygon was surveyed following criteria defined in the national mine action standards. If necessary, the polygon was extended up to a certain point after an additional polygon was created. APOPO followed the common practices of CMRS, with slightly different box search techniques, adapted to the TSD capabilities.

	BLS number	Class	Polygon size	Boxes surveyed	Boxes surveyed manually	Boxes surveyed by TSDs	SMART records	TSD box coverage	Submunitions (complete)	Submunition halves	ERW	Undefined indications
1	13117	B1.2	202,189	75	19	56	63,913	46%	17	1	6	3
2	13120	B1.2	195,569	60	15	45	56,349	50%	1	1	0	0
3	13119	B1.2	262,375	62	16	46	59,056	51%	10	0	0	1
4	13118	B1.2	132,185	50	9	41	51,824	51%	4	2	9	3
	Total		**792,218**	**247**	**59**	**188**	**231,142**	**2**	**32**	**4**	**15**	**7**

Knowing the TSD limitations with regard to working hours, it was decided that the team would conduct the survey using the TSDs in the early morning and would continue the survey later on using its manual assets, following the standard CMRS box search methods. The evaluation project ended on 31 December 2020 and the data in this report represents the work that was done within this two-month period. APOPO continued the CMRS phase beyond the project timeline.

4.2.2. ITEMS FOUND

The TSDs found 32 submunitions, 4 submunition pieces and 15 other items of ERW. The fact that the TSDs successfully indicate on submunitions and their pieces, with their mixed explosive compositions, is proof that their training is working well.

Submunitions (complete)		Submunition halves		Other ERW	
US BLU42	22	US BLU42	2	Chinese 60 mm type 27 mortar	7
US BLU26	10	US BLU26	2	Chinese 82 mm type 30 mortar	3
				Chinese 43 mm M 46 hand grenade	3
				USSR 80 mm PG2 rocket	2
Total	**32**	**Total**	**4**	**Total**	**15**

4.2.3. CLUSTER MUNITIONS TECHNICAL SURVEY WITH TSDs

When the project entered the CMRS phase, the TSD team already had a long operational experience of working with the dogs and the SMART system in vegetated areas. The main adjustment was the internal box search methodology. In traditional box search methods, there are normally four search units working together, either manual deminers or short leash dogs. It was clear that due to their long search range, it would be too crowded if they put four TSDs in the same box; it was therefore decided to create a method that included only two TSDs working in each box in parallel.

4.2.3.1. WORKING SET-UP

The team was divided into two sections. Each section had two handlers and two TSDs. One section was led by the team leader and another one by the deputy team leader. Both sections worked in the polygon in parallel. Each section leader had a tablet with the ArcGIS Collector Application, and they moved from one box to another, following the commonly used CMRS methodology. The grid was created in advance using ArcGIS Pro.

The sections operated between 6:00 and10:00 using the dogs. From 10:00 to 14:00, the deputy team leader stayed with the dogs at the control point and the other four handlers were led by the team leader as a five-person manual team, searching additional boxes using metal detectors.

4.2.3.2. TSD BOX SEARCH TECHNIQUE

The section leader leads his two dogs and handlers into the box and marks its centre. Due to the high vegetation, a three-metre light aluminium pole with a flag on top is used. The flags can be clearly seen by the handlers and give them a better sense of orientation in the box.

The section leader decides whether the box will be split from north to south (0– 180) or east to west (90–270). A total of 25 metres is measured from the centre of the box and flags put on either side to mark these points. Return azimuths are double-checked and the handlers receive a half box each to search.

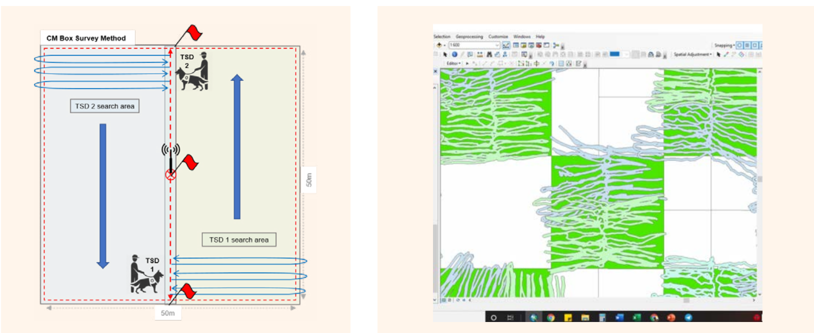


Figure 10 – Box survey method (left) and example of the SMART application (right)

The TSDs search along lanes 25–27-metre in length, perpendicular to the centre lane; the distance between search lanes is at most three metres, similar to minefields. The objective is to survey at least 50 percent of the area of the box. The SMART application tracks progress and shows the square metres on the screen – something the handlers continuously observe.

TSD indications are immediately investigated by the handlers, and after any finding of a cluster munition remnant, the section stops the survey and moves to the next box. In the CMRS context, there is no need to use the beacon dropper, since the handlers can walk everywhere and effectively measure the indication distances, and collect the coordinates.

4.2.4. METHODOLOGY KEY POINTS

4.2.4.1. SEARCH OFFSET

During the first CMRS task, there was a challenge related to box division and search direction accuracy. For example, if the section leader decided to divide the box from north to south, he should have placed the flags 25 metres from the centre, towards 0° and 180°. A lack of accuracy can cause serious offsets in the search, and as a result, the box might have to be surveyed again. Direction should be measured carefully, guiding the handlers to walk with the flags and point the compass towards them, until the section leader confirms that they are exactly on 0° and 180°. The reverse direction must also be measured before the section starts the search.

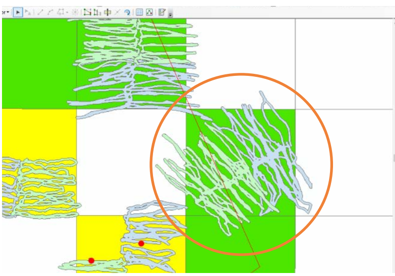


Figure 11 – Example of an offset search

Figure 12 – Handler walking to mark the box division

The box centre location should also be carefully defined and the section leader should wait until there is maximum accuracy, before continuing with the division records.

4.2.4.2. MARKING OBSTACLES AND MANUAL SEARCH

Throughout the TSD working hours, section leaders might encounter specific areas within the boxes, where the TSD are limited, such as when sharp vegetation or termite hills are encountered. These pockets are marked on the ArcGis Collector, and after the TSDs have finished their work the team returns to these areas to complete manual survey, before starting survey in new boxes.

4.2.4.3. INDICATIONS

The distance between indications is measured manually since staff members are allowed to walk over the area without prior clearance. The average distance between a dog indication and target in the CMRS phase was 169 cm from the target. The average indicating distance between dog and handler is 14 metres. The number of undefined indications was 7 out of 59, or 11.8 percent of indications. This is considered to be acceptable.

	BLS number	Working days	AVG productivity p/ dog p/day	AVG productivity p/day after merging	AVG distance from indication	AVG distance of indication from handler	Size of area confirmed as CHA	Size of area reduced	% of area reduced
1	13117	11	1,453	1,322	179	17.3	113,289	88,900	44%
2	13120	9	1,565	1,408	175	15.5	42,998	152,571	78%
3	13119	5	2,953	2,775	176	11.8	84,862	177,513	68%
4	13118	4	3,239	3,042	145	12.3	45,001	87,184	34%
	Total	**29**	**2,302**	**2,136**	**169**	**14**	**286,150**	**463,985**	**63%**

4.2.5. MANUAL FOLLOW-UP AND LEVEL OF CONFIDENCE

Manual follow-up activities continued throughout the CMRS phase. Two CMAC manual teams checked all the boxes surveyed by the TSDs and conducted full clearance of the CHA that was created during the survey. The manual teams did not find any items in areas surveyed by the dogs. The manual teams finished the follow- up in the CMRS polygons on April 30th, 2021.

4.2.6. PRODUCTIVITY

In the cluster site, productivity was significantly higher at 2,136 m^2 per dog per day. Similar to minefield work, there was lower productivity in the first polygons. It took time to adjust the methodology, reduce the time it took to move from one box to another, properly mark the centre and the separation of the box, etc. In the first two polygons, the average area searched per dog per day was 1,509 m^2, in the last two polygons it doubled to 3,095 m^2.

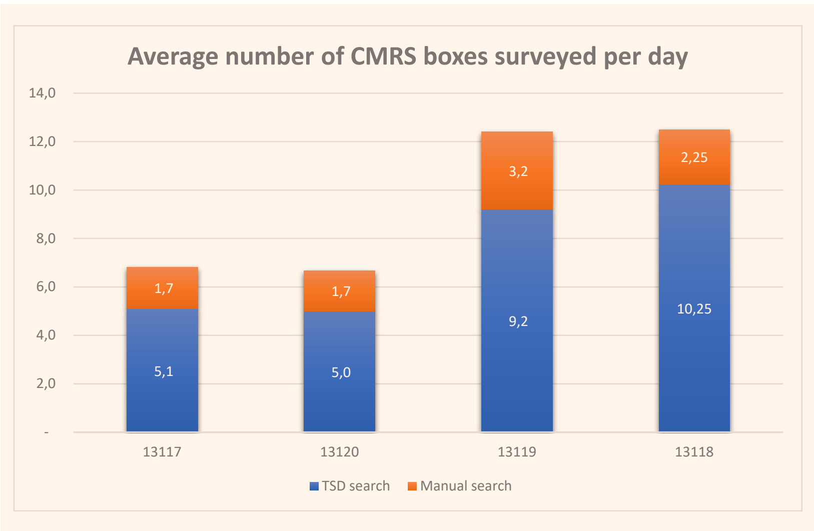


Figure 13 – Average number of boxes surveyed per day

Extrapolating data from the last two polygons means that the TSDs cleared about 12.45 boxes per day, which was confirmed by the continued work in 2021, with an average of 12+ boxes daily. For Cambodia, this means that a TSD team with four dogs working in CMRS can systematically survey approximately 12 boxes per day: 9–10 of these are surveyed by dogs, and the other 2–3 by the dog handlers using metal detectors, during the second half of the day.

Figure 14 – TSD Turbo indicating on cluster munitions

4.3. WORKING WITH THE SMART SYSTEM

4.3.1. HARDWARE AND SOFTWARE DEVELOPMENT AND UPGRADE THROUGHOUT THE PROJECT

Support for testing the SMART system was a vital component of this project. When APOPO started using the SMART, the team faced many of the same difficulties seen in 2016–2017. APOPO therefore documented the bugs and shared them with Digger DTR. Consequently, Digger released numerous updates for the server and the app and equipped APOPO with a maintenance kit that allowed them to test the different system components and update software remotely in Cambodia. The GICHD provided coordination, oversight and financial support for this process.

Figure 15 – SMART harness after a working day in the rainy season

Throughout the project, APOPO and Digger collaborated on a weekly basis and APOPO received constant assistance with troubleshooting. The SMART system was in daily use for long periods of time, including in very challenging conditions, such as hot weather, rain, moisture, parts being ripped off by vegetation, and overheating of antennas.

APOPO sent damaged equipment to Digger DTR on six occasions, and the Digger team quickly repaired it, allowing for the equipment to be rapidly sent back to Cambodia. In 2020, Digger released additional software updates and improved the hardware components in the SMART harness.

The main issues addressed during the project were the following:

- Import and export of shapefiles on the server.
- Report formats on the server.
- Lifespan of batteries and chargers.
- Bugs in network coordinates.
- Harnesses crossing between networks and loss of data.[6]
- Harness software collapse.
- Harness hardware collapse.
- Mobile application stability.
- Antenna stability and physical damage to harness Global Positioning System (GPS).
- Mobile application compatibility with Android version upgrades.
- Server software collapse.

As a result of the efficient collaboration between the two organisations, troubleshooting was drastically reduced and the TSDs spent much more time conducting technical survey. The last hardware fix was made in December 2020 and the SMART kits are now a reliable tool. Nevertheless, the systems will continue to be upgraded, if future data from the field support the upgrade requirements.

6 When working with four harnesses and two servers / antennas, both antennas have the same network name and the devices tend to cross to the nearest network, which might not be the one connected to the relevant server. This was addressed by placing the teams of two far away from each other or working with four harnesses on a single antenna / server.

4.3.2. MERGING BETWEEN DOG UNITS

One of the biggest advantages of the SMART system is its ability to automatically cancel the overlapping of a dog's search pattern. In other words, if the dog searches a certain path on its way forward and repeats it on its way back, the area will be automatically merged.

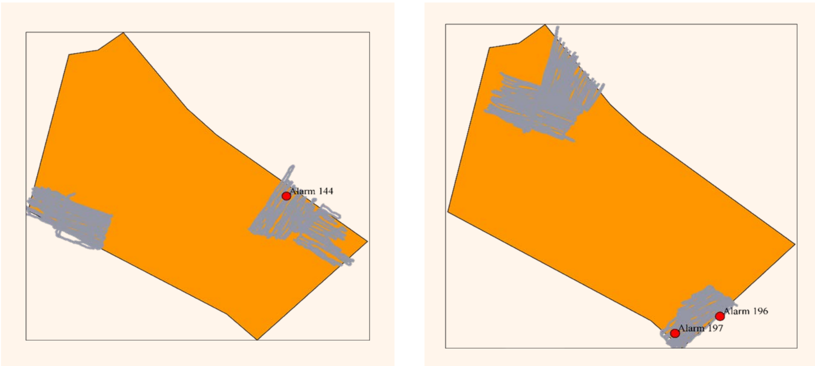


Figure 16 – Example of daily data of two dogs on a SMART server. Each dog is shown separately. Merging between dogs requires shapefile export to ArcGIS

However, this happens only within the same unit / dog. When there is overlapping between different dogs, there is no cancellation in the system, and it is visible only when the data is extracted to ArcMap. The SMART server allows a basic view of a single dog unit search, but not a combined view of several dogs altogether. The merging between dog units and the cancellation of overlaps is made later on ArcMap by the team leader, after the survey of the polygon is completed.

Throughout the project, the number of square metres reduced by merging between dog units was roughly 14 percent. The percentage of square metres lost on merging was defined as one of the internal key performance indicators in this project and affects the planning made by the TSD team leader. If in the future it is possible to enable the system to automatically cancel overlapping between dog units, the daily progress reports will be more accurate.

4.3.3. DEDUCTION OF SQUARE METERS SEARCHED WITHIN THE SAME DOG UNIT.

Although the overlaps within the dog unit are automatically cancelled, there was another challenge encountered during the project – the play and pause button on the mobile app. The same button is used for playing and pausing during the tracking mode and there are no visual indicators on the screen showing whether the application is in ‘play’ or ‘pause’ mode.

When a handler is working with his / her dog, the main focus is on the dog’s performance, behaviour and safety. The handler presses ‘play’, sends the dog to search, the dog comes back, the handler folds the leash and presses ‘pause’, moves 2–3 metres along the lane, presses ‘play’ again, sends the dog out again, and so on for 3–3.5 hours. In the first task we witnessed that after 7–8 times of play / pause, the handlers tended to get confused about whether the application was in ‘play’ or ‘pause’ mode and continued pressing the button. Once the work was complete, we repeatedly noticed that handlers discovered that they had done the opposite of what they were supposed to do, causing all the movements on the access lane to be recorded but not the dog search patterns. The result of this is that a handler loses track of their day’s work, and has to repeat the same area again the following day.

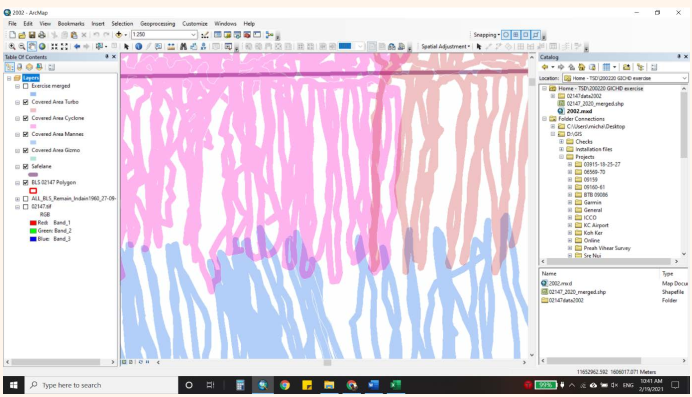


Figure 17 – Merging between different dog units on ArcGIS

On beginning the third task, it was decided that the mobile application should be kept in 'play' mode from the moment the dog was deployed until there was a break. The result is that we have additional square metres that are recorded while walking in the access lane and these square metres cannot be counted as survey. After observing the search, it was noted that on average, a dog that is deployed for a 25-metre search will cover 25 m^2 on its way forward and approximately 10 additional square metres on its way back, since some part of its route back will overlap, especially the part that is close to the handler. Therefore, if one session results in approximately 35 m^2 of dog coverage and if the handler moves two to three metres to the next session, there will be approximately three additional square metres that will be recorded and cannot be counted as survey. As a result, 10 percent was reduced from all of the daily productivity recorded on the SMART system, to be on the safe side, although the actual discrepancy is just under nine percent, on average.

A potential way of solving this problem would be to create a visible sign on the mobile screen application that shows whether the app is in 'play' mode or 'pause' mode, such as changing the background colour of the screen (currently white) to green and red. This would be enough for the handler to have a quick look at the screen, see the mode and avoid confusion.

4.3.4. DATA EXTRACTION

The SMART server is designed for data collection, and after each day in the field the team leader updates the information on the indications and the items found. The team leader generates a daily progress report from the server, which is sent to the management team in a Word file. However, when the data is exported to shapefiles, there are no details in the attribute tables, even though the information already exists on the server.

For example, the server knows that 'Indication no. 186' came from a dog unit named 'Turbo', using 'harness no. 4', with a handler named 'John' and a supervisor named 'Gary' on '04/12/2019', under the assignment 'polygon 02153' and the result was 'AP mine', model 'PMN'. However, when the shapefile is exported and brought into ArcMap, it contains only a single column attribute 'Indication no. 186' and nothing else. This causes a slowdown in the process of making progress maps, because the user has to go back to the Microsoft Word reports that were extracted by the same server and take the data from there.

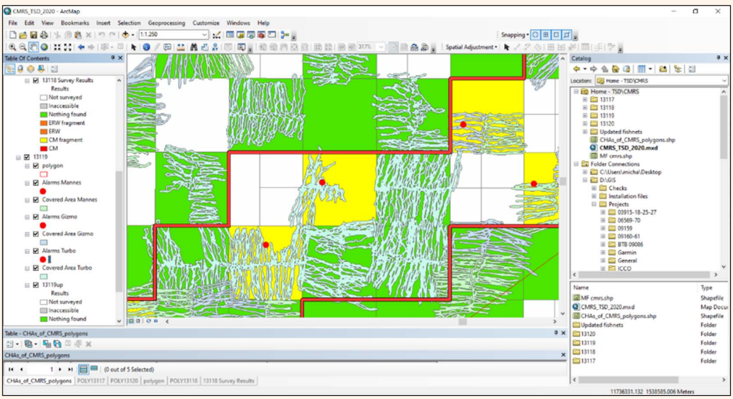


Figure 18 – Example of SMART data exported to ArcMap

4.3.5. LOCATION ACCURACY

The SMART system is a standard GPS-based system that generates data with an average two-metre offset. The feedback regarding accuracy is received only from indication points and there is a circle that shows the accuracy level for each indication. However, the accuracy level of the search lanes was unknown. If this field can be seen on the SMART mobile app, accuracy parameters for work / no work can be set. For example, if the accuracy is 10 metres, the handler should wait a little longer until the accuracy increases, before he presses 'play'. The overlapping between different dog units was likely caused by different accuracy levels of dog units and was not just a team leader planning issue. It is important to note that the SMART technology already supports RTK (real time kinetic) GPS and is capable of working in this way. However, this requires additional equipment and support, which may not always be available in the field with the mine action operators.

5. TSDs AND STANDARDS

Technical survey dogs (TSDs) are included in the International Mine Action Standard (IMAS) 07.31 (February 2020), Accreditation and operational testing of Animal Detection Systems and handlers. The role of TSDs is also described in IMAS 09.40 (March 2020), Animal Detection Systems – Principles, Requirements and Guidelines. Finally, the manner in which TSDs should be deployed is described in IMAS 09.41 (February 2020), Operational procedures for Animal Detection Systems.

The IMAS specify that animal detection systems (ADS) used for technical survey (TS) should be accredited following the long leash search pattern, thus working in 10 x 10-metre boxes or other configurations that may be found in a future operational scenario. During accreditation, the TSDs must indicate mines within 1.25 m of the centre of the mine, and must not give more than four false indications, while searching a minimum of 400 m2. For TS application purposes, the acceptable indication distance for accreditation (which was expected to be greater than 1.25 m depending on environmental circumstances) must be defined by the National Mine Action Authority.

Since these guidelines were under development during the project, APOPO added an internal TSD accreditation standard operating procedure (SOP) that provided instructions on accreditation in 25 x 50-metre areas with targets and natural vegetation. Since the publication of the revised IMAS guidelines, APOPO has used the IMAS standard to amend its accreditation SOP.

Figure 19 – TSD accreditation box, 50 x 25 metres, APOPO SOPs

Throughout the revision of the ADS chapters, the GICHD was involved with the SMART TSD evaluation project in Cambodia, which provided the field experience for the revision of the IMAS guidelines.

In 2019, the ADS chapter in the Cambodian Mine Action Standards was officially revised, and TSDs were included. Different methods of TS and the reduction of areas using ADS are included within the Cambodian national standards land release criteria and principles.

6. INTEGRATION WITH OTHER TECHNOLOGIES

6.1. GEOGRAPHIC INFORMATION SYSTEM (GIS) SUPPORT

The Swiss Mine Action Reduction Tool (SMART) system server has proved to be very useful for track and trace purposes, but it is not built to monitor the progress of technical survey dogs (TSDs) for strategising and decision-making. It became immediately clear that there should be continuous GIS support in place, which extracts the data from the SMART server and builds the necessary progress maps on which land release decisions can be made. This is something that can be discussed with the manufacturer to include in the next software batch, or for the operators to find alternative internal solutions through their own GIS support.

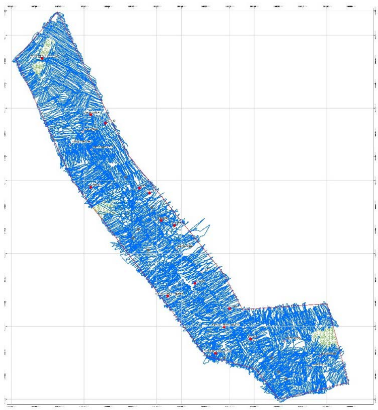


Figure 20 – Example of a polygon survey completion map made on ArcMap with data from a SMART server

GIS support to the SMART TSD activities is vital. The survey process using TSDs is relatively fast, and maps should be created immediately after task completion. The team cannot move onto the next task until the management has made decisions based on the survey results map.

Any SMART TSD project must have constant GIS support, to collect the data and create the maps as fast as possible. The amount of information collected throughout the SMART TSD work requires a full-time GIS and IT operator, who is responsible for all data collection, creation of maps, and troubleshooting for the SMART system. Most mine action organisations have such support in place, but it needs to be taken into account when planning TSD implementation.

6.2. UNMANNED AERIAL SYSTEMS

The use of drones for aerial survey is crucial for the planning and the quality management of the process. APOPO has been using drones in Cambodia for all its tasks since 2018. Drones are a very useful tool, especially for combining the work of animals with machines and manual deminers, as they allow better planning and task distribution between the assets. Drones also locate rivers and streams, significant elevation changes, pockets of very dense vegetation, such as bamboo or termite hills, that need to be considered during planning. This project was also supported by aerial survey, using DJI Mavic 2, for the desktop study of each polygon.

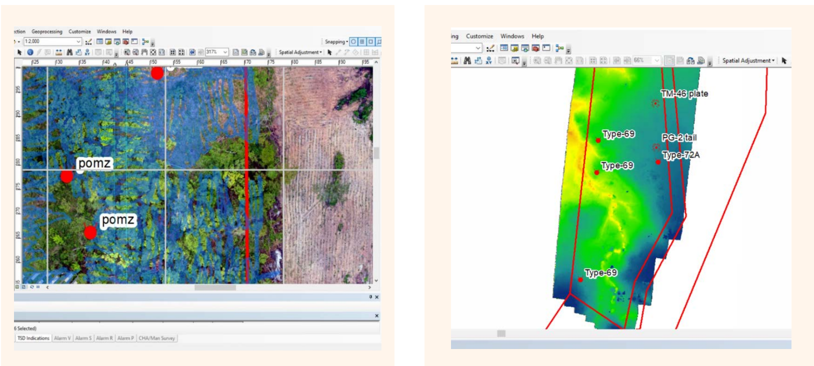


Figure 21 – Orthophoto (left) and data elevation model (right)

Drone flight plans were created and executed using the free version of DroneDeploy. Image processing was made with Agisoft software that was donated to APOPO. An example of the pictures obtained with the drones using this software is given in Figure 19 (p. 50).

6.3. BEACON DROPPER

The beacon dropper is a remotely-controlled system allowing the handler to drop a beacon when the dog indicates, and assists the deminer in finding the TSD indication location through a beeping sound emitted by the beacon.

Figure 22 – Beacon dropper system

The system has two components:

- The first is the beacon dropper and beacon dropper control. These were built by Mr. Philippe Schellekens, one of APOPO's partners in Belgium. The first version had a range limitation, and the second version allowed the drop to be located within a 30-metre range, which is enough for the current context.
- The second is the beacon and beacon finder control. There are several models on the market and the current model was selected due to its light weight, battery lifespan and water resistance.

The beacon can be located during the manual target investigation process by using the beacon finder control, causing the beacon to play a repetitive sound, similar to a 'key finder' device. The beacon dropper works within a 30-metre range and the beacon can react with a sound within a 10-metre range.

7. CONCLUSIONS

The main objective of this project was to evaluate and validate the Swiss Mine Action Reduction Tool (SMART) system for technical survey (TS) over an area of 576,000–960,000 m^2, document its performance and investigate whether this system could increase the efficiency of land release in dense vegetation without site preparation.

Despite the time it took to develop the most effective technique and the challenges with the SMART system, after a six-month working period it was clear that the method worked faster than expected. As a result, additional polygons were added to the project. APOPO was also keen to evaluate the system in cluster munition remnant survey (CMRS) which was agreed with the GICHD. Eventually, the project covered 1,434,882 m^2 of mine-contaminated area and 792,218 m^2 of cluster munition-affected area.

The selection of the operational scenarios in this project was made based on the following criteria:

- Local context of low-medium density areas with low-density mined areas that would require extensive coverage to see if this could be completed faster without compromising quality and the level of confidence in land release.
- Systematic survey patterns over a long-term period that could demonstrate whether the dogs were reliable in locating explosive ordnance and therefore building confidence in the process.
- Sectoral need to have faster area reduction tools through systematic methods.

A high level of confidence in the use of technical survey dogs (TSDs) was established through a validation process using full metal detector coverage as a follow-up to TSDs. No additional items were found in areas searched by the dogs. This is the result of two factors: firstly, the choice to limit the distance between search lanes to one–three metres, which led to a 50 percent coverage of the area according to the calculation methodology.

Secondly, the dogs were able to detect items further away than anticipated, probably due to a wider odour plume as a result of absorption of the scent into the vegetation.

In mine-affected areas, the project showed that systematic survey using the SMART system methodology is highly efficient, compared to other existing methods used in the same context. Even if the distance between the search lanes is decreased leading to a higher coverage of area, the elimination of vegetation cutting, and the 25–27-metre detection range should give the SMART system a significant cost efficiency advantage for executing TS, in comparison to other methods.

In CMRS, the pace of traditionally-used manual tools is significantly higher than in minefields. Specific benefits include:

- The ability of the TSDs to sniff out targets in vegetation, which manual deminers with metal detectors struggle to reach.
- Facilitation of quality management through traceable survey that allows better management and decision- making.
- In manual method CMRS, boxes are often skipped because they require significant vegetation cutting before metal detectors can be used. Deploying TSDs using the SMART can reduce the number of skipped boxes.

More time is required to fully understand the cost effectiveness of the SMART system in CMRS in comparison to existing methods.A SMART system dog team in CMRS is a six-person / four-TSD team that is expected to be able to survey 420,000 m^2 per month on average, approximately 12 boxes per day, and costs 163,000 USD per year in Cambodia. Manual CMRS teams normally have 10 team members. Organisations and operators can compare their own productivity and the cost data of their teams with the data and costs of deploying the SMART system.

Quality management of TSD is no different to the prerequisites for animal detection systems (ADS) outlined in the International Mine Action Standards chapters. ADS are always tested in operational conditions, through a daily capability test of a certain area that is quality checked with metal detectors.

In addition, ADS require additional pre-deployment quality management activities, focused on training the animal, training the handlers, evaluating the quality of their 'bond' and training team leaders to identify behavioural changes, as well as addressing them through ongoing training. When looking at the schedule of the project and the amount of training days over the period, it is clear that training is an integral part of the operation, and it must be taken into account. There is no 'plug and play' with ADS, and this is certainly the case with TSD.

There are always areas for improvement. Through this project APOPO learned about the optimal character required in a dog for this type of activity. The adjusted criteria for initial dog scouting led to the procurement of more suitable dogs and resulted in fewer dropouts. It also affected the training schemes and preparation of TSD handlers and TSD team leaders for future tasks. Fortunately, APOPO has a strong pipeline of dog trainers in Europe and anticipates being able to source up to 12 technical survey dogs every year (three teams). It takes about 12 months to source a TSD, train it, match it with a handler and accredit it for the field.

One of the most critical tools in this methodology is the 'track and trace' system. It is fundamental in being able to manage TSD progress effectively. During the project, improvements were carried out efficiently thanks to the robust project design which integrated the work of implementation partners, APOPO, Digger DTR and the GICHD. Further improvements related to software and hardware stability have been suggested. One significant upgrade suggested is to use a Differential Global Positioning System (DGPS), which would greatly increase the level of accuracy. The current GPS system has a two-metre offset and is quite variable. This was also noticed when integrating SMART data from several dogs (according to the data, some of the searches overlapped, whilst in reality they did not). On average this effect is cancelled out, but DGPS would be a major (albeit costly) improvement. A second major upgrade would be to provide better data management on the server component of the SMART system, so ArcGIS becomes superfluous, or to provide a better data integration with ArcGIS to minimise the amount of manual work.

During this project, TSDs became a more familiar tool in the mine action sector and APOPO has developed additional techniques that bring its advantages beyond systematic TS. TSDs are currently used on roads in South Sudan, where their long reach and the SMART functionality accelerate the process, provide track and trace records daily, and reduce the dependency on vegetation cutting on the road shoulders. There was an additional TSD team set up in Angola in 2021. Following on from the project results and the satisfaction from the tool and techniques developed, APOPO has decided to expand its dog programme and is currently building up additional TSD teams to work in Southeast Asia and to meet the growing demand for TSDs in other countries. Working in urban areas may also be possible, but the track and trace system will have to be changed / upgraded, to overcome the physical obstacles in an urban environment, and to allow for work inside buildings, for example.

The whole project team, the GICHD, APOPO and Digger DTR, would like to thank the City of Geneva (Ville de Genève) for their generous contribution and support throughout the project. In addition, sincere thanks should be forwarded to the Cambodian Mine Action Centre for their long- standing partnership and commitment.

8. LIST OF ABBREVIATIONS

ADS	Animal detection system
AP	Anti-personnel
CHA	Confirmed hazardous area
CMAC	Cambodian Mine Action Centre
CMRS	Cluster munition remnant survey
EO	Explosive ordnance
ERW	Explosive remnant of war
GICHD	Geneva International Centre for Humanitarian Demining
GIS	Geographic information system
GPS	Global Positioning System
IMAS	International Mine Action Standard
IMSMA	Information Management System for Mine Action
MDD	Mine detection dog
MDR	Mine Detection Rat
SHA	Suspected hazardous area
SMART	Swiss Mine Action Reduction Tool
SOP	Standard operating procedure
TS	Technical survey
TSD	Technical survey dog
UXO	Unexploded ordnance

All photos used in this publication are courtesy of APOPO, Digger DTR and NPA.

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