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The Advanced Ordnance Teaching Materials (AOTM) program leverages recent advances in the accessibility of 3-D printing to raise the quality of humanitarian explosive ordnance disposal education worldwide.

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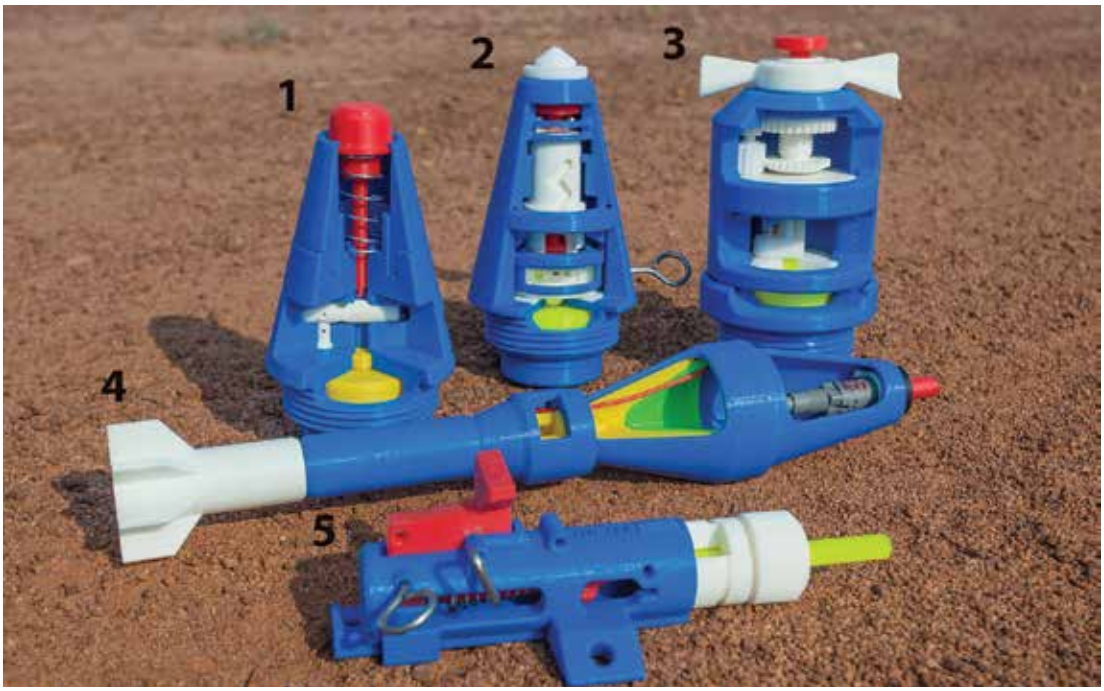

Five SOTS items:
1. Top left—point-detonating projectile fuze with setback-armed slider
2. Top center—point-detonating projectile fuze with setback and centrifugal arming using locking balls and slider-detent
3. Top right—vane-armed aircraft bomb fuze with impellor and rotor
4. Middle—point-initiating, base-detonating high explosive anti-tank round with piezoelectric element
5. Bottom—pressure, pressure-release, tension, tension release booby-trap with cocked striker

All photos courtesy of Nick Street.

Regardless of geographical location or native language, explosive ordnance disposal (EOD) technicians must understand common key concepts. The Advanced Ordnance Teaching Materials (AOTM) program addresses a fundamental aspect of EOD education: ordnance fuze functioning. To assess the risks associated with handling ordnance effectively, it is essential to understand how ordnance fuze mechanisms function. Successfully teaching these principles remains challenging, even in more advanced EOD programs.

This issue extends worldwide to a multitude of ordnance-remediation programs. Many of these programs, such as those in Southeast Asia, continue seeking assistance in developing long-term EOD-response capabilities. Using the example of how Europe addresses unexploded ordnance (UXO) challenges by maintaining national capacities for UXO response validates this approach; countries benefit from developing sustainable indigenous assets capable of dealing with these issues as they are discovered. Instead of pursuing the idea of "total clearance," this focus confronts UXO as it arises.

The SOTS instructor support materials are based on active learning pedagogy, which requires students to be active participants in the learning process. One exercise presented in this approach is to let students assemble the models before receiving instruction and then allow students to explain how they think it operates.

To meet these objectives, most nations operate one or more EOD schools. In the Asia-Pacific region, EOD schools continue to request donor assistance for facility and infrastructure improvement, curriculum development and third-party technical advisers and instructors. These assistance packages often lack affordable and effective hands-on training materials.

Inert ordnance training aids from Golden West Humanitarian Foundation's (Golden West) extensive library are often requested by humanitarian operators. Unfortunately, due to factors detailed in this report, distribution of these materials is limited. Golden West has struggled to find a solution to this problem.

The Advanced Ordnance Teaching Materials (AOTM) program aims to close the gap between the availability and need for EOD education, and endeavors to bring a set of universally applicable training materials to the EOD community. Ultimately, by improving the quality of EOD instruction, AOTM will increase operator safety within the profession.

Training Aids

The highest quality training aids currently available are created by removing explosive materials from live ordnance, a practice known as **inerting**. The closest alternative to inert ordnance are replicas made from various materials, such as plastic or wood, that seek to replicate the original appearance of ordnance. In programs where neither of these resources are available, classrooms rely on paper or electronic representations. Even when physical training aids are available, the absence of professional teaching tools or materials may mean that these aids are not used to full potential.

Inert ordnance. Inert ordnance training aids are handmade craft products. Because quality, functionality and appearance vary significantly, the products have inconsistent instructional value. Other issues associated with inert training aids include:

1. Limited supply of donor ordnance
2. Requirement of highly specialized technicians for production
3. Inherent risk to technicians
4. Labor-intensive craftsmanship (2–20 or more hours for one item)
5. International shipping regulations that severely limit distribution

Due to significant demand for these products, as well as the issues listed above, inert ordnance training aids cannot be distributed in quantities meeting the global need. Additional factors limit usefulness of inert ordnance for basic-level EOD training:

1. The complexity and small size of internal mechanisms obscures tactile observation of the device's function.
2. The fragility of inert ordnance prevents repeated disassembly, which is particularly acute in complex mechanisms (fuzes were never designed for disassembly).
3. Conventional machining and fuze composition limits the degree to which the device can be cut away to expose functional components.

Replicas. Ordnance replicas generally consist of one or more parts that amalgamate the fuzing mechanisms of the item they represent. Replicas are commonly nonfunctioning; the components representing any fuze mechanisms have very limited or no mechanical functionality relative to the item they represent.

Typical production of replica ordnance employs hobby techniques such as silicone mold production for resin casting, while wood turning and other labor-intensive methods have also been used. Historically, lack of cost-effective fabrication methods for small-batch production limits manufacture of mechanically complex replicas.

Replicas excel at representing mechanically simple items such as projectile bodies, improvised explosive devices and simple ordnance fuzing (such as mines utilizing Bellville

springs).[1] There is a notable market absence for items such as mechanical time fuzes.

Due to the accuracy of their external appearance, replicas are primarily useful for teaching ordnance identification during basic-level EOD education. Ordnance identification is important but does not substitute for a comprehensive understanding of fuze functioning. Moreover, the current range of capabilities represented in most replicas cannot adequately illustrate fuze functionality.

Publications. Publications are a pillar of EOD education and one of the most valuable resources available to field operators. The humanitarian community primarily relies on publications such as ORDATA II and unclassified military documents.[2] While a critical source of information about specific ordnance items for advanced EOD operators, publications have significant limitations for teaching basic fuze functionality to entry-level trainees.

A student from the Cambodian Mine Action Centre explores the mechanism in a vane armed bomb fuze during IMAS EOD level 1 training.

The level of formal education among EOD students in post-conflict developing nations, in which the majority of the sector's work takes place, is another factor limiting usefulness of publications for entry-level education. In countries with low exposure to formal education and literacy (such as Cambodia and its civil-war generation), Golden West EOD instructors found that traditional teaching methods relying on written materials are significantly more difficult than "hands-on" methods. Even in countries where students acclimate to using print sources, the value of physical training materials remains undisputed.

AOTM Approach

AOTM identifies two distinct categories for ordnance training materials

1. Aids that teach generic ordnance and fuze functionality (PIBD, MT, BD, etc.)
2. Aids that teach ordnance-specific functionality (i.e., how an MJ-1 rocket fuze functions, etc.)

AOTM addresses both categories. The first deals with generalized fuze functionality, which is a universal requirement for all basic EOD education and is addressed through creation of a Standard Ordnance Training Set (SOTS). This set includes 10 models representing the most common fuzing mechanisms found in ordnance. While these mechanisms are true to generic fuze functionality, they are not specific to any single fuze design.

SOTS includes a comprehensive set of instructional resources to ensure students receive the best possible education. These support materials include lesson plans, multimedia materials (i.e., PowerPoint presentation slides), quizzes and exercises. The set also includes open-source reference materials. The entire SOTS package is delivered in a single Pelican Case™ for easy transport and storage in field conditions worldwide.

The SOTS package is tailored to meet the learning objectives of the European Committee for Standardization Workshop Agreement (CWA) for EOD Competency Standards for Humanitarian Mine Action Levels 1 and 2.[3] This training set addresses CWA EOD Knowledge Base Competency Standards for

- Explosive ordnance recognition
- Explosives theory and safe handling of explosives

Addressing specific fuzes, the second category of training models is more applicable to high-risk munitions where EOD operators need precise knowledge. Another application trains EOD teams on threats specific to their area of responsibility. To serve these purposes, AOTM is building a database of 3-D ordnance models true to the original items. Some of the models are ready, but the goal is for the database to continue growing and serving the community's needs. These can

be enlarged to scale to facilitate ease of use but are otherwise replicas of the originals.

The AOTM production process overcomes the aforementioned limitations by providing the ability to

- Create complex, cut-away windows to represent internal workings of ordnance
- Design custom representations based on specific training objectives
- Meet economical, low-volume production demands, international shipping constraints and on-demand production quotas
- Produce models with mechanical functionality, more detailed models and models with simplified mechanical functionality to teach basic EOD concepts
- Enlarged-to-scale items and components

Pedagogy

Faculty partners from Singapore University of Technology and Design and Massachusetts Institute of Technology have focused their contributions on incorporating current methodologies for mechanical education into the SOTS package. SOTS training materials are based on active learning methodology, engaging students in problem-solving and other activities requiring active participation. This methodology proved effective in teaching mechanical concepts.[4]

An example SOTS classroom exercise consists of dividing students into small teams; each team receives a disassembled model to reassemble and is asked to explain how it works to the class. The students perform the exercise prior to any instructor explaining how the mechanisms function. The instructor then guides the class to answer any questions that arise through group analysis.

The Instructor Guide is a professional lecturer's guide and provides step-by-step directions on how to run lessons. This includes guidance on how to set up the class, facilitation activities and suggested teaching methods. Included in the digital resource kit, the guide is provided as a bound book accompanying SOTS.

Technical Specifications

SOTS includes 10 ordnance-based training models, each addressing major learning objectives for completion by October 2014. The design of all 10 models is loosely based on existing fuzes but features adaptations optimizing their presentation in order to clearly demonstrate each applicable learning objective. Table 1 outlines each of the models SOTS includes and the fuze mechanisms they represent.

The physical models included in SOTS were designed with the following constraints:

1. Mechanisms must be easily resettable to the unarmed position.
2. Mechanisms must be true to ordnance.
3. Mechanisms must be clearly visible.
4. Models must be physically robust and able to withstand repeated disassembly, tabletop drops and general classroom rigors.

Recent advances in affordability and accessibility of additive manufacturing enabled design and production of these models within constraints of the nonprofit sector. The engineering required to design these models is substantial, and some items require more than 100 design hours. The nature of this process is iterative, requiring multiple rounds of fabrication and redesign. 3-D printing offers the only known solution responsive and cost effective enough for this purpose. The printers used to fabricate AOTM models use Acrylonitrile Butadiene Styrene or ABS plastic, which proved well suited for this purpose.

Sustainability

The Office of Weapons Removal and Abatement in the U.S. Department of State's Bureau of Political-Military Affairs (PM/WRA) provided full funding for the first round of AOTM development, which includes completion of SOTS. While still operating within the nonprofit framework, the AOTM project can continue serving the mine action community by expanding the database of available ordnance models.

In order to ensure the program's continued evolution and serviceability, sales of models to humanitarian demining organizations in good international standing directly support the AOTM funding structure. PM/WRA, in cooperation with Golden West, will determine an organization's purchasing eligibility. All PM/WRA implementing partners are expected to be eligible and can place orders at a web store (http://eodtrainingaids.com/).

In Summary

The AOTM program is poised to provide access to effective ordnance-training aids worldwide. By leveraging recent advances in additive manufacturing (3D printing), AOTM brings innovation to the humanitarian EOD classroom. These items have the potential to positively impact the quality of EOD education across the sector.

See endnotes page 51

Item Code	Arming Mechanism	Firing Mechanism	Forces	Type
SOTS – M1	Safety pin	Firing pin	Springs	PD
	Detent	Point detonating	Acceleration	
	Bore riding pin		Setback	
			Impact	
SOTS – M2	Safety pin	Firing pin	Springs	PD
	Detent	Point detonating	Acceleration	
	Slider		Setback	
			Impact	
SOTS – M3	Safety pin	Firing pin	Springs	PD
	Detent	Point detonating	Acceleration	
	Slider		Setback	
	Locking balls		Free flight	
			Impact	
SOTS – M4	Time delay	PTTF	Electrical	PIBD
		PIBD	Impact	
		Piezoelectric		
SOTS – M5	Arming key	Belleville spring	Pressure	Anti-personnel mine / pressure
			Victim actuated	
SOTS – M6	Rotor	Base detonating	Mechanical	BD
	Escapement		Deceleration	
SOTS – M7	Safety pin	Cocked striker	Springs	Pressure, pressure release, tension, tension release
			Tension	
			Victim actuated	
SOTS – M8	Escapement	Graze (leaf spring)	Centrifugal	PD / graze sensitive
			Setback	
			Mechanical	
			Impact	
SOTS – M9		Capacitor	Proximity	Variable time / proximity
SOTS – M10	Impeller/propeller	Point detonating	Springs	PD
		Firing pin	Impact	

Table 1. Outlines each of the models included in SOTS and the fuze mechanisms they represent.
All tables courtesy of Golden West.

Item Code	Description	Type	Notes
SOTS – VTM1A1	Explosive firing train	Instructor's video	Match, Paper, Wood
SOTS – VTM2A1	Shear pin	Animation	
SOTS – VTM3A1	Shaped charge	Animation	
SOTS – VTM4A1	Platter charge	Animation	
SOTS – VTM5A1	Spit-back	Animation	
SOTS – VTM6A1	Battery firing device	Animation	Thermal battery
SOTS – VTM7A1	Powder train time fuze	Animation	
SOTS – VTM8A1	Chemical delay	Animation	
SOTS – VTM9A1	Mechanical delay	Animation	Wire through lead

Table 2. Supplementary instructor materials included in SOTS to demonstrate concepts best taught using multimedia.

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