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EDUCATING THE NEXT GENERATION OF EXPLOSIVES SPECIALISTS

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ABSTRACT

Explosives accidents have claimed the lives of more than a thousand people around the world since the turn of the Millennium. Added to the loss of life has been the significant loss of defence capability and infrastructure. Many of the accidents have been caused not by failure of design, but by human failure. Much of the human failure can be attributed to the lack of competencies, skills and adequate training of the people concerned. This paper describes some of the initiatives being taken in the UK and in the European Union to ensure that workers in the explosives community have the skills and competencies required to safely sustain activities involving explosives. It will describe the development and evolution of a range of explosives competencies and the training and qualifications framework being developed to generate and maintain the competencies. Finally, the paper will refer to some of the novel training approaches which are being applied.

EXPLOSIVES SAFETY

Since the turn of the Millennium there have been a number of well publicised explosives accidents around the world. Annex A, taken from Reference 1, details the majority of these. One of the characteristics of these accidents is that they frequently have catastrophic consequences.

In Lagos, Nigeria an ammunition dump exploded, the explosion created mass panic which subsequently led to the death of nearly 1000 people, most of whom were children. Another explosives accident aboard the Russian submarine led to the loss of 118 sailors, a loss of significant defence capability and serious political destabilisation of the Putin Government. In Holland an explosion involving fireworks destroyed 200 houses and killed 22 people, whilst in France an explosion involving ammonium nitrate destroyed a major industrial facility, killed 30 people and injured around 2000. The consequence of explosives accidents is frequently serious in human, economic and political terms.

<u>Figure 1.</u> Explosion at Enschede, 13 May, 2000.
Examining the cause of explosives accidents invariably reveals that human error or failure is a major contributory factor. The Enschede incident in Holland was initiated by a deliberate act by a malcontent. However the catastrophic consequences were also a result of management failure, breaches of the explosives regulations and a failure to understand that storing fireworks inside steel iso-containers generates sufficient confinement to maximise the violence of the event.

One of the torpedos loaded on the Kursk is known to have been dropped prior to embarkation and this may be linked to the torpedo explosion which, the official report suggests, led to the loss of the submarine and its crew. In both cases it was the actions of individuals or the failure to act in an appropriate way which contributed to the accident. Had the firework company known how pyrotechnics might behave under confinement, would they have used iso-containers for storage? Had personnel on the keyside known about the sensitivity of the fuel oxidant system of the Kursk torpedos, would they have been embarked after being dropped?

Effective explosives safety depends on people making the right decisions at the right time. It depends upon people having the necessary competence to carry out their jobs properly. The concept of competence is well recognised in UK safety management. Much of UK safety legislation calls for "competent people" in roles that affect safety. In the case of explosives, this will be in all stages of life, from the formulation of new explosives in the laboratory, through manufacture, storage, transportation, use and disposal.

THE MOD AND UK POSITION

The MOD has an exemplary record in explosives safety. This is in part due to the rigor of the regulatory framework that has evolved over many years. It is exempt from the main civil explosives Acts of 1875 and 1921, but has put in place a regime which is at least as rigorous than the civil legislation. All explosive ordnance entering service is subjected to classification by a competent authority and to a safety and suitability for service assessment. Once in-service, explosives are stored, transported, processed and used in a highly regulated way. At each stage of life explosives will be in the custody of competent personnel, whilst the maintenance of the regulations and staffing of the assessment process will require a high level of expertise. Currently the MOD probably has, or has access to, sufficient numbers of explosives competent personnel to sustain all of its activities involving explosives.

The future however is less certain. Twenty years ago explosives ordnance for UK armed forces was developed in MOD research labs, the explosives were synthesised and manufactured in MOD production facilities. There was a large and expert explosives quality assurance function, the Ordnance Board and CINO had more than 400 safety specialists to assure safety. In the armament depots and Air Force bases there was a cadre of ordnance and explosives specialists. Another substantial group of explosives specialists were employed on the nuclear weapons programme. Many of the competent staff in place today derived their experience and competence during this period when they had one employer (the MOD). Most acquired their broad experience by being encouraged to work in the varied environments which MOD could provide. Many in post today will have had experience of research, production, quality, assessment and project management. Today the situation is very different. Manufacture and production are firmly in the private sector and more recently, much of the explosives and ordnance research community has made a similar transition. Nuclear weapons are produced in privatised facilities. There is limited movement of staff between these different organisations and it is difficult for MOD to recruit or develop explosives specialists with broad experience.

Whilst the stovepiping of organisations in the explosives business has had an impact on the breadth of experience, the general contraction of the explosives business in the UK has had a major impact on the numbers of skilled specialists. Added to this many of the UK specialists were recruited in during a growth period in defence science and technology in the 1970s and are approaching retirement. A lack of recruitment in the late 1970s and 1980s has left a demographic trough, wherein there are insufficient skilled explosives specialists to replace those who will be leaving government service in the next few years.

EUROPEAN UNION

The picture in the rest of the European Union is similar. Many countries are reporting similar problems in finding explosives specialists to fill key posts, especially in the explosives safety area. Scandanavian countries are also reporting that the shortage of skills is also affecting the performance of explosives and ordnance related industries. However, it is not just a problem of shortage of people, but a problem with the competence of people already in the business.

LEONARDO da VINCI PROGRAMME

Cranfield University together with KCEM, a Scandinavian explosives competence organisation, have joined with other EU partners in a project funded by the European Union Leonardo da Vinci programme. This programme is aimed at replenishing explosives expertise, though vocational training and education across the EU. The purpose is not only to ensure the supply of specialists in key explosives safety functions, but also to maintain European competitiveness in the ordnance and explosives industrial sector.

To achieve this purpose the project will:

a) Identify the competencies required to sustain a safe and competitive explosives industry in the EU.
b) Establish the current and future needs for these competencies in the EU.
c) Develop training and educational programmes designed to develop this range of competencies

d) Develop a range of novel education and training packages that form part of the programme
e) Develop explosives qualifications which will be recognised and accepted across Europe
f) Reverse the decline in expertise, knowledge and skill in European explosives business

COMPETENCIES

The first challenge in defining competencies is decide the scope of the explosives occupational sector to whom they apply. There are large numbers of people working with explosives in the military, and civil sectors. Members of the armed services transport, store, use and dispose of explosives on daily basis. In the civil sector explosives are used in the mining, offshore and demolition businesses. Various levels of expertise are required of the explosives process worker, the research scientist, or the managing director of a business handling explosives. An analysis will be made of all of the jobs involving work with explosives and a judgment made about those which legitimately fall into the sector.

Once the boundaries are established for the explosives sector, the competencies required of different jobs within the sector will need to be established. A competency framework will be developed needed to cater for both the breadth of the business and the depth of expertise appropriate to those jobs.

In a number of areas there are already established competency frameworks that support specific business sectors. The Defence Ordnance Safety Group (DOSG) has produced a set of functional competencies for explosives safety practitioners. Annex B shows an excerpt from the competency framework showing the differing level of expertise which needs to be applied. A job which requires someone to develop policy and regulation for explosives safety management requires a high level of expertise, compared with someone who needs to follow the rules.

BUSINESS NEEDS

Before developing the training and education provision, it will be necessary to establish what the current and future requirements will be for people with these competencies. This will require engagement with employers of explosives workers. It will require a degree of crystal ball gazing to predict future level of industrial activity. Notwithstanding the needs of industry, there will continue to be a need for a minimum number of explosives competent staff in defence ministries so long as explosives ordnance forms a component of defence capability.

QUALIFICATIONS AND ACCREDITAION

To demonstrate competence there is increasingly a requirement to demonstrate that workers possess a qualification or other independently assessed level of attainment. In the UK there is currently a major initiative to rationalise the complex and confusing range of qualifications. The new National Qualifications Framework at Annex C has been developed, which aligns vocational qualifications and higher education awards. Unlike the previous version, it does not distinguish between general, vocationally related and occupational qualifications preferring a continuum approach. Nevertheless, universities and higher education establishments will continue to offer more general qualifications, whilst employers will be more focussed on occupational qualifications that are more closely related to a workers ability to do a specific job.

A second initiative in the UK is the recent formation of the Sector Skills Councils whose purpose is to:

- Reduce skills gaps and shortages.
- Improve productivity, business and public service performance.
- Increase opportunities to boost the skills and productivity of everyone in the sectors workforce, including action on equal opportunities.
- Improve learner supply, including apprenticeships, higher education and national occupational standards.

The sectors which have greatest relevance to explosives specialists are the Science, Engineering and Manufacturing Technology Skills Council (SEMTA) and COGENT, which is the council that looks after the chemicals industry. The former has already sponsored the development of National Occupational Standards and underpinning National Vocational Qualifications for one part of the explosives sector, that of explosives clearance specialists. The approved National Occupational Standards and qualifications structures for the NVQs/SVQs shown below are available from cdoy@emta.org.uk.

1 Planning and Management of Munition Clearance Operations – Level 4
2 Supervisory Management of Munition Clearance and/or Search Operations – Level 3
3 Search for Munitions and/or Specified Targets – Level 3
4 Search for and Disposal of Munitions – Level 3
5 Contribute to the Search and/or Disposal Function – Level 2
6 Provide Support for Search or Munition Clearance Operations – Level 1

These can be placed on the new qualification framework as shown in Table 1.

New Qualifications Framework	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Explosives Clearance								
Plan & Manage					**NVQ4**			
Supervise			**NVQ3**					
Search for Munitions			**NVQ3**					
Search & Dispose of Munitions			**NVQ3**					
Contribute to Search		**NVQ2**						
Provide Support to Munitions Clearance	**NVQ1**							

Table 1. Qualifications for Explosives Clearance Specialists.

Explosives clearance represents only a small proportion of the UK explosives business, however, it is one of the few areas where occupational standards and qualifications have been developed. As part of the Leonardo programme, the framework will be extended to cover all occupational groups in the explosives business. As an example, in the manufacturing sector a similar table could be developed with broadly similar functions and qualifications. In the defence acquisition field a similar set of framework could be developed for explosives specialists. Because of the high level of expertise required of some of these functions, the emphasis would be towards higher education awards, rather than vocational or occupational qualifications. Table 2 shows **an example** of some of the functions in both the manufacturing and safety management areas.

New Qualifications Framework	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Explosives Manufacture								

Plan & Manage Manufacture					NVQ4/BSc			
Supervise production			NVQ3					
Contribute to Production		NVQ2						
Support to Manufacture	NVQ1							
Explosives Safety Management								
Develop policy and regulations							MSc	
Advise IPTs on Ordnance Safety							MSc	
Classify & Qualify Explosives					BSc			

Table 2. Examples of Explosives Qualification Framework.

Extending these tables to include all occupational groups, will require consultation with employers across both the civil and public sectors. Ideally, this should be done in partnership with the appropriate sector skills council. It will also be necessary to decide the qualifications appropriate to each of the occupations listed in the framework. In some areas there are already qualifications. The universities provide a limited number of relevant masters programmes, whilst professional bodies such as the Institute of Explosives Engineers provide accreditation for another group in the sector. However, the overall picture is one in which there are insufficient qualifications which can be used to support a demonstration of competence across the wide range of explosives related occupations. A key deliverable for the project will be to populate the matrix with a range of suitable qualifications to cover all aspects of the explosives business. These qualifications should be recognised, not only in the UK, but across the European Union.

TRAINING AND EDUCATION

Having established and expanded the competency and qualifications framework, training and education provision will also need to be expanded to enable staff to develop their competencies. The expansion will partly be through the provision of conventional courses such as those delivered at the UK Defence Academy at Shrivenham. Cranfield University offers Masters courses on Explosives Ordnance Engineering and a range of short courses on explosives related subjects. These courses are appropriate for comparatively small numbers of higher education level students. However, this conventional teaching approach has disadvantages in that it takes place away from the workplace and often lacks a clear occupational context. Furthermore employers are increasingly reluctant to release valued workers for full-time postgraduate courses. Students are also reluctant to be away from their place of work at a time when there is almost continual change. To respond, the universities are developing modular masters programmes that can be done part-time. Furthermore, much of the material can be delivered on-line through the internet. A number of e-learning products are now being employed for this purpose. These products enable text, voice, film and conventional lecture presentations to be delivered on line at a time that suits the student. Coursework is exchanged by e-mail and course chat lines are used to enable the tutor to communicate with students and for students, who could be anywhere in the world, to communicate with each other.

For occupational and vocational training and education, the techniques described above can be used, however, there also needs to be close link with the workplace. The Scandanavian project, reported at reference 2, was designed specifically for process workers in the munitions manufacturing area. A total of 15 students from various parts of Sweden were provided with distance learning material such as CDs and written materials. A network of video conferencing links were used for teachers to communicate with students individually and in a group. The aim of this one-year educational pilot programme was to develop the potential of the students and to make them more flexible and adaptable in the workplace. The business advantage for the employers was to be able to react with agility to changes in technology and the demands of the market. The pilot has been very successful and the Leonardo programme will build on this success.

Whether the qualification is a Masters degree or a vocational qualification, the educational foundations will be similar and much of the educational material will be common to both. As part of the Leonardo programme a core of educational foundation material will be developed to underpin vocational and general qualifications.

CONCLUSION

- The competence of personnel has a significant impact on explosives safety.
- The UK and European Union are losing expertise and skills in explosives science and technology.
- A competency framework should be developed to embrace all occupations working with explosives.
- Occupational standards and qualifications should be developed to support the competencies.
- Training and educational provision should be expanded to support the acquisition of explosives.

REFERENCES

1. http://news.bbc.co.uk/1/hi/world
2. “It-Based distance Method for a Vocational Education Programme for Qualified Operators and Technicians in the Swedish Explosives Industry”, Hans Wallin, presented to the 30th DoD Explosives Safety Seminar, Atlanta, August 2002.

Annex A

Chronology of Worldwide Explosives Accidents

2003

19 Sept, Afghanistan Two people killed by accidental explosion near Bagram air base.
3 Aug, Pakistan. At least 52 people were killed and around 150 injured in an accident in the Diamir district. The explosion involved blasting explosives and completely destroyed an entire village.
27 March, Northern France At least three workers killed in blast at an explosives factory which ripped through the plant, a forth is still missing. Homes and shops nearby were also damaged in the blast, which appeared to be the result of an industrial accident, traced to a workshop making cartridges which contained flammable material.
4 February, Pakistan At least 17 killed - among those schoolchildren – and 35 more injured – some critically, when a container loaded with explosives for making firecrackers blew up at a dry docks.
3 Feb, Lagos, Nigeria, 33 People died in an accident involving a cache of illegal explosives.
1 January, Mexico At least 28 killed and 50 injured following an explosion and fire which started at an illegal fireworks stand, which engulfed market stalls and nearby buildings.

2002

21 November, Ecuador At least five killed and 300 wounded in series of blasts which lasted several hours. Explosions appear to have been set off when a grenade was dropped accidentally at the arsenal of the towns army munitions dump.
23 October, India At least 23 killed in separate incidents caused by fireworks explosions - at least 13 killed in ain an explosion at a warehouse, caused by an electrical short circuit, most of victims were staying in a hotel on the top floor of the building; and a huge explosion at a fireworks factory killed 10 workers and injured 8 others.
23 August, Indonesia At least 12 killed and 16 injured after sacks of fireworks exploded on board a bus.
10 August, Jalalabad At least 26 killed and 80 injured in accidental blast, which could have been caused by negligence in the storing of large quantities of explosives, in a warehouse of a construction firm, where a recent explosion occurred.
28 June, Afghanistan At least 19 killed and 15 injured in a series of explosions at a weapons depot. An initial blast triggered a series of smaller explosions, destroying and damaging many nearby houses and shops.
12 May, Iraq Two soldiers killed in accidental munitions explosion.
13 May, Iraq One solider killed in accidental munitions explosion near Hilla.
25 May, Iraq One soldier killed and one injured in an apparent accidental blast at a former Iraqi munitions dump.
11 March, China 21 killed and 12 more injured in explosion on a long-distance bus, thought to have been caused by fireworks being transported.
30 January, Lagos More than 600 deaths, with more than 1,000 people still missing – mostly young children, three days after explosions at a military armoury.

2001

29 December, Indian 19 killed in accident involving landmines. Not sure whether they were laying mines or undergoing training to defuse them.
21 September, France Thirty people are killed and 2000 injured in an explosion at a petrochemical factory in the south-western city of Toulouse.
16 August, India: At least 25 people are killed in an explosion at a government-owned dynamite factory in the southern Indian state of Tamil Nadu. Officials say the blast was caused by an "accidental ignition".
10 August, Portugal: Five people are killed and another is injured in an explosion at a fireworks factory in Caldelas, Portugal.
11 July, Afghanistan: Three people are injured in an explosion at an ammunition depot at Darulaman on the southern outskirts of the Afghan capital, Kabul.
21 July, Russia: Three people are killed and four others are injured in a blaze at an army ammunition depot in the Buryat region of eastern Siberia. The accident was reportedly caused by lightning.
8 June, Vietnam: At least four people are injured and 100 homes are damaged in an explosion at an army base in central Vietnam. Reports say 3.5 tons of explosives and ammunition blew up at an army warehouse in Hoa They, south of the Vietnamese capital, Hanoi.
1 June, Pakistan: At least nine people are killed and four others are injured in an explosion at an illegal fireworks factory in Lahore.
7 March, China: At least 37 pupils and four teachers are killed in a blast at a primary school which was being used for manufacturing fireworks in Jiangxi province, eastern China. A doctor at the scene said pupils had been putting fuses into firecrackers at the time of the explosion.
3 March, Guinea: At least 10 people are killed after a fire starts a series of explosions at an ammunitions dump at army base in the Guinean capital, Conakry.

2000

5 August, China: At least 21 people are killed and 25 others are injured in an explosion at an illegal fireworks factory in China's Jiangxi province. Officials say the blast, which destroyed a five-storey building, was probably caused by a dropped cigarette.
12 August, Russia: 118 sailors are killed after the sinking of the nuclear submarine Kursk which was taking part in an exercise in the Barents sea. There is controversy over the cause but it is thought by many to be the result of an explosion on board.
15 May, Spain: Five people are killed and 18 others are injured in a fire and explosion at a fireworks factory in Rafelcofer in Spain. Reports say the blast could be felt 3.5 km (2 miles) away.
13 May, Netherlands: Twenty people are killed in an explosion at a fireworks factory in the Dutch town of Enschede. Another 950 people are injured in the blast, which destroyed about 400 homes.
14 March, Mexico: Three people are killed and 17 others are injured in an explosion after sparks ignite hundreds of fireworks at a religious festival in Santa Ana Jilotzingo.
13 January, China: Up to 22 people, including 11 children, are killed in a blast at an unregistered fireworks factory in Anhui province, eastern China.

Annex B

Ordnance, Munitions and Explosive Safety Functional Comptencies

COMPETENCE	Level	PERFORMANCE CRITERIA	OUTCOME
OME1. Development and application of appropriate legislation, regulation, MOD policy and best practice.	Awareness	OME1.1 Works safely and effectively within an OME Safe system of work.	Produce and maintain a safe system of OME work
	Practitioner	OME 1.2 Demonstrates an understanding of the basis for explosive regulation.	
		OME1.3 Ensures compliance with legislation, regulation, MOD policy and best practice.	
		OME1.4 Demonstrates an awareness of hazards applicable to OME and their effects.	
	Expert	OME1.5 Contributes to and produces effective regulation or legislation.	
		OME1.6 Demonstrates a thorough knowledge of hazards applicable to OME and their effects	
OME2. Knowledge of energetic material characteristics and interaction with other materials.	Practitioner	OME2.1 Demonstrates an awareness of properties and effects of energetic material.	MoD satisfies its safety obligations to people, property and the environment by providing accurate advice to IPTs, site operators, users etc.
		OME2.2 Takes informed decisions based on knowledge of the properties and effects of energetic materials.	
		OME2.3 Demonstrates knowledge of environmental effects on energetic material.	
		OME2.4 Demonstrates an awareness of the effects of external stimuli to energetic material.	
	Expert	OME2.5 Explains & predicts the effects of energetic material on the environment, people and infrastructure.	
		OME2.6 Explains & predicts environmental effects on energetic material.	
		OME2.7 Demonstrates a comprehensive understanding of the effects of external stimuli to energetic material.	

Annex C

Framework for Higher Education Qualifications		**National Qualifications Framework(revised)**					**National Qualifications Framework (existing)**
D	(Doctoral) Doctorates	8		Vocational Dips			**5 Higher Levels**
M	(**Masters**) Masters degrees, Postgraduate certificates & diplomas	7	Key skills	Vocational Certs & Dips		[NVQ 5]	
H	(**Honours**) Bachelors degrees, Graduate certificates & diplomas	6		Vocational Certs & Dips			**4 Higher Levels**
I	(**Intermediate**) Diplomas of HE & FE, Foundation degrees, Higher National Diplomas	**5**	Key skills	Vocational Certs & Dips		[NVQ 4]	
C	(**Certificate**) Certificates of Higher Education	**4**		Vocational Certs & Dips			
		3	Key skills	Vocational Certs & Dips	A Levels	NVQ 3	**3 Advanced**
		2	Key skills	Vocational Certs & Dips	GCSE (Grades A* - C)	NVQ 2	**2 Intermediate**
		1	Key/ Basic skills	Vocational Certs & Dips	GCSE (Grades D - G)	NVQ 1	**1 Foundation**
		Entry	Basic skills	Certificates of achievement			**Entry**