

## **Education and Training in the Explosive Sector**

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### **ABSTRACT**

The manufacture and use of explosives, propellants and pyrotechnics underpins a significant part of the European Union economic and industrial activity. An understanding of explosives science and technology and the competence to harness it is central to maintaining European explosives capability, national security, and in sustaining a competitive European industry. There is a perception, and some evidence, that in Europe, competence levels in this key technological area are being eroded. In several member nations a high proportion of the most experienced and knowledgeable personnel are retiring or nearing retirement. Urgent efforts are therefore underway in some partner nations to replenish this expertise. The U.K. together with Sweden, Norway, Finland and Italy are taking part in a Leonardo Da Vinci programme to develop a comprehensive framework which describes and categorizes the competences of all workers engaged in the manufacture or use of explosives. This paper will outline i) the procedures used to develop the competences for U.K. workers and ii) the development of National Occupational Standards for the U.K. and Europe.

### **INTRODUCTION**

On Friday 21<sup>st</sup> September 2001, 30 people were killed and 2,500 were injured in an explosion at an ammonium nitrate factory in Toulouse in France. On 22<sup>nd</sup> September 2001 the Mayor of the city of Toulouse called for all potentially hazardous factories and plants to be relocated away from areas where people live. On 5<sup>th</sup> September 2003 the Investigating Judge for this incident dismissed the case against nine of the eleven employees, due to lack of evidence. Today the scientific explanation for this disaster still remains unanswered. Countless investigations are still ongoing to try to establish the long chain of events which occurred in Hangar 221 in Toulouse where the tragic explosion took place. On 16<sup>th</sup> August 2001 25 people were killed in India due to an accidental ignition which led to an explosion in a Government owned dynamite factory. 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 Kursk 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. These are just a few examples of accidents involving explosions around the world.

Since the turn of the Millennium (Reference 1), there have been a number of well-publicised explosives accidents around the world. One of the characteristics of these accidents is that they frequently have catastrophic consequences, not only on humans but also on the country's economic and political arena. Examining the cause of explosive accidents often reveals that human error or failure is a major contributory factor, as an example one of the torpedoes loaded on the Kursk is thought 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.

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 U.K. safety management. Much of U.K. 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.

Thirty years ago explosives ordnance for U.K. 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).

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 explosive specialists with broad experience. The general contraction of the explosives business in the U.K. has had a major impact on the numbers of skilled specialists. Added to this many of the U.K. specialists were recruited 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.

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, through 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:

- Identify the competencies required to sustain a safe and competitive explosives industry in the EU.
- Establish the current and future needs for these competencies in the EU.
- Develop training and educational programmes designed to develop this range of competencies.
- Develop a range of novel education and training packages that form part of the programme.
- Develop explosives qualifications which will be recognised and accepted across Europe
- Reverse the decline in expertise, knowledge and skill in European explosives business.

The project is now in its second year and this paper highlights the results from activities which have been completed so far, together with activities planned for the forthcoming year.

### **Occupational Mapping**

In order to define the competencies of the workers in the explosives industries, the scope of the explosives occupational sector must first be established. Cranfield university together with the MoD and other industrial companies approached the Science, Engineering and Manufacturing Technology Agency (SEMTEA), which is one of the UK Sector Skills Councils (SSC) (more information on SEMTEA and the SSC is given in section 3.1).

SEMTEA together with Denise Clark Ltd were asked to develop the national occupational standards and national vocational qualifications for occupations in explosive substances and articles with the help of Cranfield University, U.K. MoD and other organisations. Denise Clark Ltd carried out the following occupational and functional maps, together with the competencies.

An occupational mapping analysis has been carried out on all of the jobs involving work with explosives within the U.K. The occupational mapping analysis gives information on:

- the numbers employed in each industry as a whole
- the numbers of people employed in explosives substances and articles (ESA) occupations

- identification of the relevant roles
- characterization of the significance of the industries concerned
- issue, trends and factors affecting education, training, skills and qualifications of those involved in explosives handling work and
- the existing education and training arrangements in each industry.

The types of explosives substances and articles (ESA) organisations which have been identified in the occupational map and the number of workers employed in these organisations for the U.K. are presented in Tables 1 and 2 respectively.

Table 1 Types of explosives substances and articles (ESA) organisations in the U.K.

Commercial Industries	Public Organisations	Military
<ul style="list-style-type: none"> <li>• Special effects &amp; fireworks</li> <li>• Quarrying ,mining, demolition &amp; construction</li> <li>• Oil &amp; gas escape mechanisms</li> <li>• Seismology</li> <li>• Avalanche control</li> <li>• Motor industry</li> <li>• Research, testing &amp; disposal</li> <li>• Defence manufacturing</li> </ul>	<ul style="list-style-type: none"> <li>• Transport &amp; logistics</li> <li>• Police</li> <li>• Fire prevention &amp; firefighting</li> <li>• MoD</li> <li>• Training &amp; education</li> </ul>	<ul style="list-style-type: none"> <li>• Royal Air Force</li> <li>• Royal Navy</li> <li>• Army</li> </ul>

Table 2 Population of workers involved in explosives substances and articles for the U.K.

Sector	Managerial	Supervisor	Technician	Operator	Other	Total
Armed forces	4841	5410	2921	27,884	2	41,058
MoD	412	274	358	548		1592
<sup>1</sup> DSTL	17	46	15	152	16	246
<sup>2</sup> QinetiQ	138	120	178	237	65	738
<sup>3</sup> Others	N/A	N/A	N/A	N/A	N/A	632,508

<sup>1</sup>DSTL is the Defence Science and Technology Laboratories and is a part of the MOD

<sup>2</sup>QinetiQ is a commercial company involved in defence research and testing

<sup>3</sup>these include all the commercial industries from Table 1 plus police, fire prevention & firefighting, transport & logistics, and training & education

### Functional Analysis

The next part of the procedure is to establish a process for analysing the key functions of a sector or an occupation; this is known as a 'functional analysis'. The functional analysis provides a functional description of the entire occupational area in terms of outcomes. Table 3 gives details of the 13 key roles which have been identified for occupations in explosives substances and articles.

These 13 primary key roles can be broken down into subsidiary roles which allows the key roles to be achieved. Examples for key role 1 (research and develop explosive substances and articles) and key role 11 (dispose of explosive substances and articles ) are shown in Figure 1.

Table 3 The main functions of explosives substances and articles occupations.

Key Roles	Description
1	Research and develop explosive substances and articles
2	Develop and manage explosives safety
3	Test and evaluate explosive substances and articles in field trials
4	Manufacture explosive substances and articles
5	Maintain and repair explosive substances and articles
6	Procure explosive substances and articles
7	Store and move explosive substances and articles
8	Transport explosive substances and articles
9	Manage explosives facilities
10	Prepare and use explosive substances and articles for engineering and entertainment purposes
11	Dispose of explosive substances and articles
12	Enable the public and armed services to continue their regular activities in peace and war by controlling and removing munition threats
13	Support the explosive substances and articles function

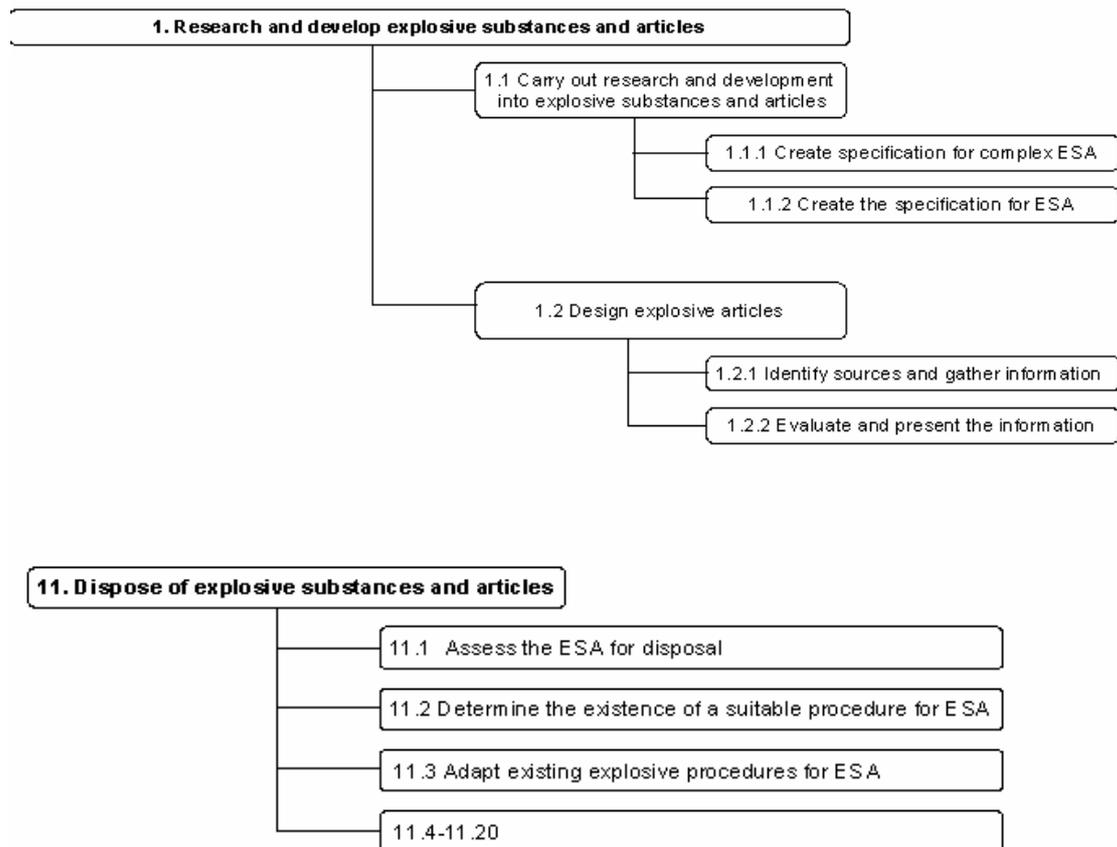


Figure 1. Examples of key role 1 and key role 11 and their subsidiaries

### 1.1.1 Create the specification for complex explosives substances and articles

<p><b>Contexts</b></p> <ol style="list-style-type: none"> <li>1 Customer requirements: where a complex detailed technical requirement is provided; where a general description of requirements is provided</li> <li>2 Constraints: resource limitations; possible conflicts of interest</li> <li>3 Solutions for addressing customer needs: existing; adaptations to existing solutions; novel</li> </ol>	
<p><b>Criteria</b> – You need to:</p> <ol style="list-style-type: none"> <li>a. work safely at all times, complying with health and safety, environmental and other relevant regulations and guidelines</li> <li>b. wear appropriate PPE</li> <li>c. identify or confirm accurately the customer’s underlying needs</li> <li>d. assess objectively the feasibility of the customer’s requirement</li> <li>e. determine objectively the best methods by which these needs can be addressed</li> <li>f. explain fully and clearly to the customer and any other relevant people the basis for any decisions</li> <li>g. identify accurately any operational constraints that could affect the research and development of the explosive substance and/or article</li> <li>h. provide relevant and timely advice to the customer, expressed in a way that meets their requirements</li> <li>i. alert the customer promptly to any additional information or implications that may be in their best interests</li> <li>j. consult others who may be affected and build their feedback into your specification</li> <li>k. create a specification that clearly addresses all the customer’s requirements and your success criteria</li> <li>l. create a clear and concise specification that contains sufficient detail to enable research planning to take place</li> <li>m. confirm the customer’s level of satisfaction and use the information to make further improvements</li> <li>n. maintain the requirements of confidentiality at all times</li> </ol>	<p><b>Knowledge</b> – You need to know and understand:</p> <ol style="list-style-type: none"> <li>i. health, safety and environmental and other statutory legislation, regulations and safe working practices and procedures governing explosives and their implications for your area of work</li> <li>ii. the relevance of PPE</li> <li>iii. your organization’s strategic and operational policies and objectives</li> <li>iv. how to carry out a feasibility study</li> <li>v. how to establish appropriate success criteria</li> <li>vi. alternative options for meeting the customer’s needs</li> <li>vii. the underlying needs of the customer’s requirements</li> <li>viii. when and how to challenge a customer’s brief</li> <li>ix. when and how to advise a customer to pursue a different course of action</li> <li>x. the constraints that may affect your decisions and plans</li> <li>xi. your own level of authority and those of others with whom you work</li> <li>xii. the requirements of confidentiality</li> </ol>

Figure 2. The competency for key role 1.1.1, ‘Create the specification for complex explosives substances and articles’.

### Competencies

From the functional map the competencies for each outcome is written, an example of a competency for key role 1.1.1 (Create specification for ESA) is presented in Figure 2. From Figure 2 it can be seen that the criteria describes the actual work the employee does in undertaking to create a specification, and the knowledge underpins the activity.

**11.1 Assess explosive substances and/or articles for disposal**

<p><b>Contexts</b></p> <ol style="list-style-type: none"> <li>1. Explosive substances and/or articles: immediately identifiable; those which require further investigation</li> <li>2. Hazards and risks caused by: complexity of the explosive substances or articles; condition of the explosive substances or articles; primary hazards; secondary hazards</li> <li>3. Information: with access to full information; with access to limited information</li> </ol>	
<p><b>Criteria -You need to:</b></p> <ol style="list-style-type: none"> <li>a. work safely at all times, complying with health and safety, environmental and other relevant regulations and guidelines</li> <li>b. wear appropriate PPE</li> <li>c. identify or confirm the identity of explosive substances or articles and its condition</li> <li>d. characterize accurately the hazards pertaining to the disposal</li> <li>e. quantify the risks of the disposal</li> <li>f. record relevant information in accordance with your organization's procedures</li> <li>g. maintain an appropriate level of confidentiality</li> </ol>	<p><b>Knowledge- You need to know and understand:</b></p> <ol style="list-style-type: none"> <li>i. health, safety and environmental and other statutory legislation, regulations, safe working practices and procedures governing explosives and their implications for your area of work</li> <li>ii. the relevance of PPE</li> <li>iii. information sources and documents that might identify the explosive substances and/or articles</li> <li>iv. the design, nature and characteristics of the explosive substances and/or articles</li> <li>v. how to identify the hazards (eg condition, primary and secondary)</li> <li>vi. how to carry out a risk assessment</li> <li>vii. any previous results of tests, trials or disposals and manufacturers' and design authorities and scientific literature</li> <li>viii. your organization's recording procedures</li> <li>ix. any confidentiality requirements</li> <li>x. your own personal level of authority</li> <li>xi. when to refer to others for more information or a second opinion</li> </ol>

Figure 3. The competency for key role 11.1, 'Assess explosive substances and/or articles for disposal'.

The worker should be able to carry out this activity in all the contexts listed in Figure 2. Another example of a competence is presented in Figure 3. The competence is for key role 11.1, 'assess the explosives substances and articles for disposal'. The total number of competencies that have either been written or taken from existing competencies for explosives substances and articles occupations is 396. In order to assess the competencies and their relevance to the explosive worker, they will be assessed by means of validation trials. These trials will be carried out during April 2005. Details and venues of the trials in the U.K. are presented in Table 4. The results of the trials will be fed back into the competencies and the competencies revised accordingly. Validation trials of some of the competencies will be carried out by the European members of the partner countries who are taking part in the Leonardo da Vinci pilot programme. Details of the European trials are also given in Table 4.

Table 4 Details of the validation trials in U.K. and Europe

<b>Key role</b>	<b>Area to be validated</b>	<b>U.K. validation site</b>	<b>European validation site</b>
1	Research and develop explosive substances and articles	Leafields QinetiQ MoD - DSTL Fort Halstead Cranfield University	U.K. - Cranfield University
2	Develop and manage explosives safety	MoD - DOSG Safety Advisers MBDA MoD - MCBU AWE Army - 11 EOD and AS of A BAE Systems	
3	Test and evaluate explosive substances and articles in field trials	MoD - DSTL Fort Halstead AWE QinetiQ MoD - DOSG Safety Advisers	
4	Manufacture explosive substances	AWE MoD - DSTL Porton Down	Sweden - Nammo Finalnd - Sverige
4	Manufacture explosive articles	Leafields MBDA Insys BAE Systems	
5	Maintain and repair explosive substances and articles	DOSG Safety Advisers (TBC) RAF operational unit RN (HMS Collingwood) MoD - DSDA (DM Kineton ATSG) MoD - DOSG Safety Advisers	
6	Procure explosive substances and articles	MoD - DPA MoD - DLO (DGM IPT) BAE Systems MBDA	Italy - Nitrex
7	Store and move explosive substances and articles	MoD - DSDA RLC 61 Sqdn MoD - DOSG (ESTC)	Italy - Nitrex
8	Transport explosive substances and articles	MoD - DSDA Army - RLC 61 Sqdn and AS of A MoD - DOSG (ESTC) MoD - DTMA	
9	Manage explosives facilities	MoD - DSDA AWE QinetiQ MoD - DOSG Safety Advisers BAE Systems MBDA	Italy - Nitrex
10	Prepare and use explosive substances and articles for engineering and entertainment purposes	Skyburst Fireworks Army - RE (Demolitions) Army - DMS Demolition Offshore	Sweden - Nammo
11	Dispose of explosive substances and articles	AWE QinetiQ MCBU Army - 11 EOD and AS of A Merseyside Fire & Rescue MoD - DOSG Safety Advisers	U.K. - Cranfield University

## QUALIFICATIONS AND ACCREDITATION

To demonstrate competence there is increasingly a requirement to demonstrate that workers possess a qualification or other independently assessed level of attainment. In the U.K. there is currently a major initiative to rationalise the complex and confusing range of qualifications. The new National Qualifications Framework shown in Figure 4 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.

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			
I	(Intermediate) Diplomas of HE & FE, Foundation degrees, Higher National Diplomas	5	Key skills	Vocational Certs & Dips		[NVQ 4]	4 Higher Levels
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

Figure 4. New qualification framework

### Sector Skills Council

A second initiative in the U.K. is the 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 (SEMTEA) 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 are available from [cdoy@emta.org.uk](mailto:cdoy@emta.org.uk). These standards and qualifications can be placed on the new qualification framework as shown in Table 5. Explosives clearance represents only a small proportion of the U.K. 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.

Table 5 Qualifications for explosives clearance specialists

<b>New Qualifications Framework</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>
Planning and management of munition clearance operations					NVQ4			
Supervisory management of munition clearance and/or search operations			NVQ3					
Search for munitions and/or specified targets			NVQ3					
Munitions search for and disposal of munitions			NVQ3					
Contribute to the search and/or disposal function		NVQ2						
Provide support for search or munition clearance operations	NVQ1							

Table 6 Examples of explosives qualification framework

<b>New Qualifications Framework</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>
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			

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 6 shows an example of some of the functions in both the manufacturing and safety management areas.

### **Qualifications Council Awards**

When the validation trials have been completed and all the 396 competencies have been amended, qualifications appropriate to each of the occupations listed in the key roles will be written. In the U.K. there are already qualifications in some areas. 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 support a demonstration of competence across the wide range of explosives related occupations. A key deliverable for the Leonardo da Vinci programme will be to populate the matrix with a range of suitable qualifications to cover all aspects of the explosives business in Europe and to give greater flexibility to the student, who may be able to study a variety of modules in different countries in order to gain a qualification in explosives.

### **TRAINING AND EDUCATION**

Having established and expanded the competency and qualifications framework, training and education provision will 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 U.K. Defence Academy at Shrivenham. Cranfield University offers Masters courses on Explosives Ordnance Engineering and a range of short courses on explosives related subjects. The universities are also developing modular masters programmes that can be done part-time. 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 (Wallin 2002) was designed specifically for process workers in the munitions manufacturing area. 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.

### **CONCLUSIONS**

The competence of personnel has a significant impact on explosives safety. The U.K. and European Union are losing expertise and skills in explosives science and technology. A competency framework has been developed to embrace all occupations working with explosives. Occupational standards have been written and qualifications are currently being developed to support the competencies. The qualifications should be recognised and offered by European countries. Training and educational provision should be expanded to support the acquisition of explosives.

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