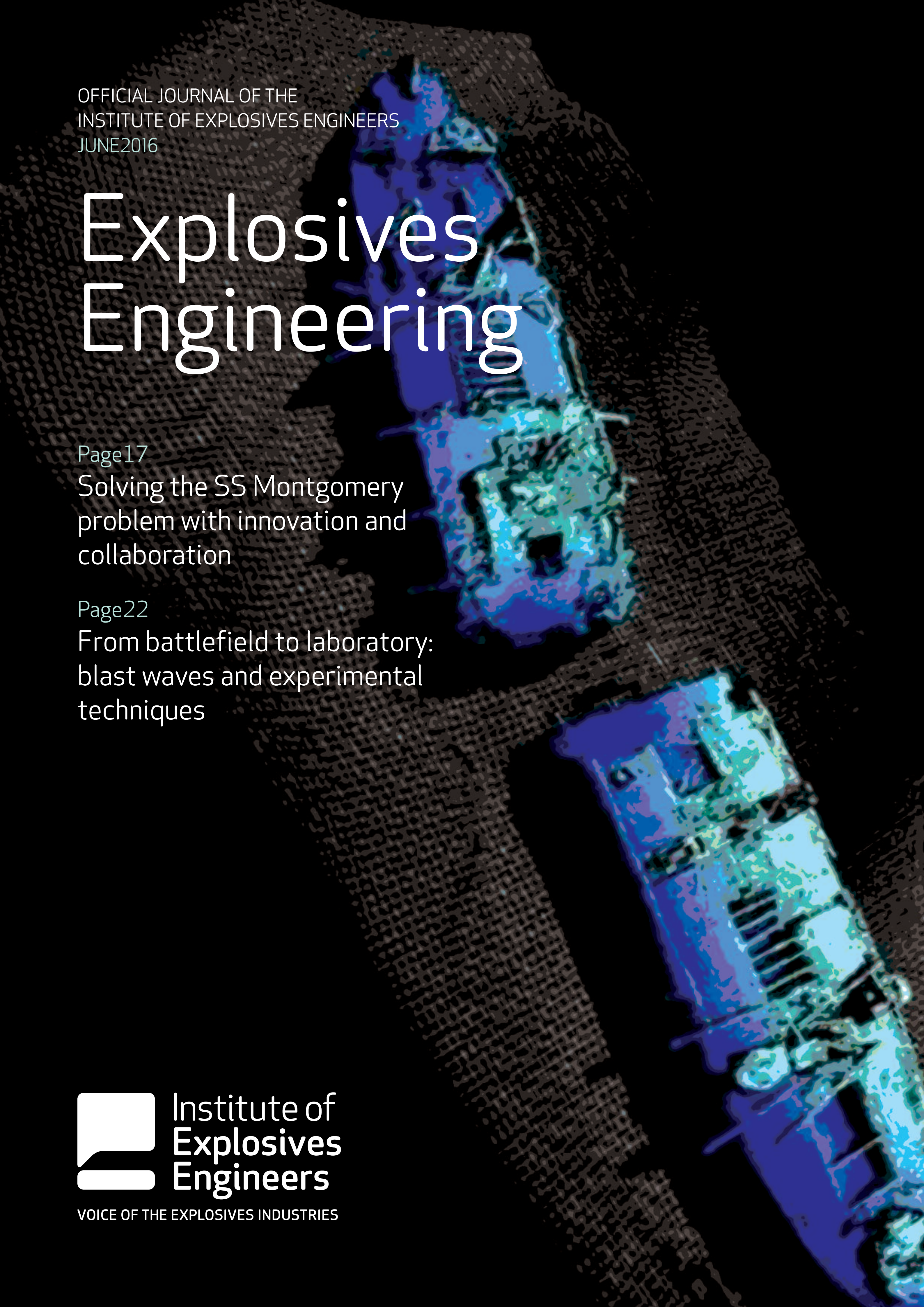


OFFICIAL JOURNAL OF THE
INSTITUTE OF EXPLOSIVES ENGINEERS
JUNE 2016

Explosives Engineering

Page 17

Solving the SS Montgomery problem with innovation and collaboration

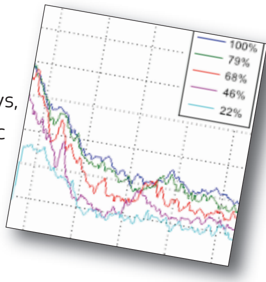
Page 22

From battlefield to laboratory: blast waves and experimental techniques

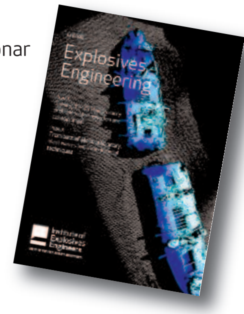
Institute of Explosives Engineers
VOICE OF THE EXPLOSIVES INDUSTRIES

Contents

Features



Regulars



Underwater sonar scan of SS Montgomery 2013.
See page 17.

Explosives Engineering
Distributed quarterly to all members of the Institute of Explosives Engineers. To non-members or for additional copies to members, including p&p.
Single copies:- UK £8.80, EU £11.20, World £12.40.
Annual subscription:- UK £34.50, EU £44.10, World £61.00

To obtain copies, contact Explosives Engineering Subscriptions at the Institute address above. Cheques should be made payable in sterling to the Institute of Explosives Engineers.

Papers, articles and letters to the Editor are welcome and should be sent to the Editor at her email address, or by post to the Institute address.

Opinions expressed in the Journal are those of the authors concerned. They do not necessarily represent the views of the Institute.

Institute of Explosives Engineers
VOICE OF THE EXPLOSIVES INDUSTRIES

Professional Affiliate of ECUK

The Institute of Explosives Engineers
Suite 3, 7–8 Mill Street, Stafford ST16 2AJ
Telephone and fax: 01785 240154
Email: secretariat@iexpe.org
www.iexpe.org

Institute of Explosives Engineers Registered Office
141 Victoria Road, Swindon SN1 3BU
Company No. 07905911
Company limited by guarantee

Editor
Diane Hall
Telephone: +44 (0)1729 840765
Mobile: +44 (0)7778 063373
Email: editor@iexpe.org
DianeTHall@aol.com

Design and Print/Production and Advertising Manager
Gordon Hunt
Gordon Hunt Design
Telephone: +44 (0)1726 832594
Email: design@gordon-hunt.co.uk

The President speaks

I was delighted to meet so many members at this year's Annual Conference, alongside our European partners from EFEE and EU Excert. We also had attendance from as far afield as Singapore and Australia. Equally, I was delighted to introduce Jon Pritchard, CEO of the Engineering Council, as our keynote speaker.

The annual event, held this year at the Telford Hotel and Golf Resort, focussed on the theme of 'Innovation' and brought together speakers from a wide range of areas to deliver a truly memorable Conference. The marketing team and specifically Nathan White along with Vicki Hall at the Secretariat who organised the event, are to be congratulated on a job well done. The bar has now been set for next year and dates/venue will be released soon!

Although it is mentioned elsewhere in this journal, I would like to take this opportunity to thank all the speakers and sponsors for their contributions in making this year's Conference a success. Without the generosity of these companies and individuals there would not be a Conference. It also goes without saying that we will be looking for speakers and sponsors for next year's event and it's never too early to start planning. Anyone wishing to present a paper, be involved in the organisation of next year's event or perhaps understand sponsorship opportunities should contact Vicki at the Secretariat.

Past President's Medal being presented to John Wolstenholme by Dave Welch.

I was particularly pleased to be able to present John Wolstenholme (Immediate Past President) with his Past President's Medal. I was unable to undertake this formally during our actual handover as we completed this in October 2015 outside the usual AGM handover mechanism. John worked extremely hard during his tenure as President, putting in place a great many foundations for the work that continues to this day, developing our Institute and improving Member benefits.

During this year's AGM the proposed amendments to our Constitution were voted on and accepted by the membership. These changes will be phased in over the coming weeks and months and whilst many of them will have no impact on you, there has been a significant revision in relation to branches. The branch system has been replaced by a less formal and more accessible structure of networking events which will be co-ordinated by the Secretariat and with funding support available to those wishing to host/organise events. The aim of this restructure is to increase the number of events held during the year for Members to access and gain CPD opportunities. The website is also being modified to allow online bookings for these events and we will inform all Members once this is live.

The importance of CPD, alongside certified qualifications, refresher training and ongoing assessment of competence has never been more important for all sectors of our industry, and recent events only serve to reinforce this.

Stay safe!

Dave Welch CEng MIMechE MIExpE
President

Emailcontact list:

President@iexpe.org	Dave Welch	President
Director@iexpe.org	John Wolstenholme	Past President
Finance.director@iexpe.org	Ian McKay	Finance Director
Vp.projects@iexpe.org	Tony Slate	Legal and Compliance
Andrew.carr2@baesystems.com	Andy Carr	Education and Training
Membership@iexpe.org	Andy Pettitt	Membership
Marketing@iexpe.org	Rob Parry	Marketing
Registrar@iexpe.org	Ken Cross	Affiliations

Please note:
A Member is trying to trace John Butterworth, President from 1983 to 1984. If you have any information please contact the Secretariat at secretariat@iexpe.org.

AGM, Dinner and Conference report


Council Members at the AGM.

On the 12th and 13th April 2016 IExpE met at the Telford Hotel & Golf Resort, Shropshire for its annual AGM, Dinner and Conference.

The AGM was led by our new President, Dave Welch. Dave introduced a new Council structure that seeks to enable innovation and deliver outputs quicker through delegation of responsibilities. There are now six new sections: Finance; Legal & Compliance; Memberships; Education & Training; Affiliations; and Marketing. The structure is manned by teams, each overseen by a Vice President whose role is to steer and report progress.

A particular contention at the AGM was the proposal to remove Branches. There was a significant debate that has helped clarify and amend the proposal. I recommended that the membership read the AGM minutes and familiarise themselves with the proposals. All appeared to agree with the common intent, which is to open more opportunities for the membership to interact. Importantly, there was recognition that the cessation of Branches does not prevent locally organised events. There were concerns raised by representatives of the Australian and Singapore Branches that were resolved or taken outside the AGM for further discussions with the President.

Three resignations from Council were announced: Paul Harris; Holli Kimble; and Nathan White. Council thanked them on behalf of the membership for their passion and support, and wished them well in their new endeavours. All were applauded by the present membership. We look forward to them continuing to support Council deliver the Institute's aspirations as volunteers and that they will, at some time, seek re-election to continue the good work.

Special congratulations go to Bruce Cochrane who received the Journal Editor's award for his significant contribution to the Journal. Journal readers will be familiar with Bruce's regular 'Tech Spec' feature where he consistently writes engaging and informative articles. Unfortunately, Bruce was unable to attend because of recent surgery; gladly he was back on his feet to receive his award in London later in the month. Bruce enjoys his writing and that he can share his considerable knowledge and experiences with others, he also gets much from it because it pushes him to explore and learn new areas; he would welcome invitations from the wider membership who would like him to write about explosives in various other contexts.


Presentation to Keynote speaker Jon Prichard from the Engineering Council by President Dave Welch.


Rob Leary of sponsor Frazer-Nash Consultancy with Dave Welch.


Frank Hirthammer of TTE Europe with Dave Welch.


Rob Parry, Vice President Marketing, presenting the Journal Award 2016 to Bruce Cochrane for his contribution to the Journal.

Ron Lancaster of Kimbolton Fireworks with Past President John Wolstenholme after his presentation.

Robert Barnes from Australia asks a question at the AGM.

The dinner was well attended.

The evening dinner introduced, what is probably the most exciting networking opportunity seen to-date, a diverse and large networking opportunity that continued through to the end of Conference. It was a pleasure to meet new members from the various occupations within our sector and to our colleagues overseas from EFEE and EUExcert. Thank you to all those that attended for making this a wonderful opportunity, special thanks to Erik Nilsson for providing the after dinner speech.

The Conference theme this year was 'Innovation', which probably attracted the largest audience to date with close to 100 delegates being present, probably the best attendance to-date. The theme is probably the most significant factor delegates consider when planning attendance; feedback forms asked those who attended to propose a theme for next year. However nominations for the theme are welcome from the wider membership, simply email the Secretariat. A particular interest this year was the wide occupation representation presented, with: offshore; mining/quarrying; defence; fireworks; special effects; all contributing and learning from each other.

The Conference opened with the Keynote address from Jon Prichard, Chief Executive Officer of the Engineering Council, who introduced the work of the Council and the importance of obtaining Chartered status both to the individual member and to the engineering industry as a whole. This was followed by a most interesting presentation by Andy Pettitt, Executive Vice President of Spex Group who highlighted the offshore incident on the BP Deepwater Horizon rig in 2010 which resulted in serious consequences with many deaths and an environmental disaster with a reported 5 million barrels of oil spilled into the Gulf of Mexico. In response to this disaster, an explosives-based system was developed and the presentation demonstrated how an innovative use of explosives and propellants, backed by rigorous design, modelling and testing allows for a system that today would prevent a similar occurrence if deployed.

Frank Hirthammer, Senior Partner Manager of TTE Europe, one of the sponsors of the Conference, explained that as a result of the EU Commission Directive 2008/43/EC, issued in 2008 and its extension 2012/4/EU, manufacturers, distributers and end users have to consider requirements for the identification and traceability of explosives for civil use within the EU. The date for implementing this directive was April 2013, and targeted the manufacturers and importers of explosives. For this, the creation of specification analysis for marking explosives together with manufacturers and national authorities in Germany began. His company worked together with EFEE and other European organisations to gain more experience in the market. Since 2013, a European partner network was built to provide consultation in every EU country.

Rob Leary and David Wyse, both Senior Consultants at Frazer-Nash Consultancy Ltd, and one of the sponsors of the Conference, gave a fascinating presentation "Solving the SS Richard Montgomery problem with innovation and collaboration". The ship grounded in the Thames Estuary in 1944 with a remaining approximate 1,400 tonnes Net Explosive Quantity on board. On behalf of the UK Department for Transport (DfT), Dstl and Frazer-Nash have assembled a Munitions Working Group (MWG) of Subject Matter Experts (SMEs) to investigate the problem. Different wreck management strategies have been produced. Frazer-Nash has developed a bespoke approach and software tool that utilises SME-defined probability density functions and Monte-Carlo simulation to calculate a mean mass detonation probability with associated confidence limits. The MWG's

Nathan White, who was responsible for organisation, welcomes the Conference.

The Fraser-Nash exhibition at the Conference.

Malcolm Ingry addresses the Conference.

Enjoying the coffee break at the Conference.

Visitors to the exhibition.

innovative approach demonstrates the value and success of utilising industry skills and experience.

In "The Use of explosives in underground blasting", Malcolm Ingry reported on the demise of nitro-glycerine cartridge explosives and electric detonators in blasting in mining and tunnelling and their replacement by bulk emulsions and high velocity cast primers and shock tube type detonators/electronics. An insight was given into the complex subject of blasting underground in tunnelling, and how this knowledge is not being passed on to the younger mining engineers.

Ron Lancaster of Kimbolton Fireworks addressed the Conference on his sixty years in firework manufacture and asked "Is there a future?" He traced the history of manufacture since the Explosives Acts of 1875 until the period in the 1960s when public concerns about the safety of domestic fireworks led to much concerned debate and the growth of larger public displays and a fall in the sale of domestic fireworks. Kimbolton Fireworks were probably the first company to produce the new style of aerial display. Since 1974 with the greater emphasis on health and safety, manufacture in Europe has been made increasingly difficult.

In "Innovation through re-interpretation; cross-pollination of knowledge in the explosives industry", Charlie Adcock, Managing Director of Event Horizon focussed on the work that his company enjoys the most, taking the knowledge and capabilities learned from their varied experiences and applying them in novel, interesting and innovative ways. The talk covered some of the projects that Event Horizon have been involved in over the last 20 years with particular emphasis on how tried and tested techniques from one area of the explosives world can provide elegant solutions in others.

Daniel Jubb, Rocket Engine Consultant at Falcon Projects presentation on "The Falcon project and the resonant acoustic mixing (RAM) of energetic materials" provided a background and history of Falcon and details of the Westcott facility. It discussed the challenges of mixing energetics using the standard kit and covered how Falcon addressed these issues and developed improved mixing vessels, support equipment and control/data collection software. It covered some of the static testing, which has been conducted and highlighted the remaining challenges and discussed scale up to larger production quantities.

Our thanks go to the sponsors of the event including Frazer-Nash Consultancy, ISSEE, System Design Evaluation, TTE-Europe and H&G Explosives who all mounted exhibitions at the Conference which were well attended.

Another special thank you is to the organisers, who are new to arranging this event, for their hard work, dedication, and innovation. A new team brings new ideas but on this occasion they also had to work within the new Council structure, mentioned earlier, and took the opportunity to test the limits of their freedoms. The journey that is often referred to as 'Progress' is always bumpy, so I thank the team for its patience when exploring the scope of its new delegations. Planning now begins for the 2017 event.

Rob Parry MIExpE
Marketing VP

EUExcert UK report

Report on the EUExImp Project

Meetings

Since the last report, the following meetings have taken place:

Swedish partners meeting, Tallinn, 25th January 2016

Project meeting, Rakvere, Estonia, 26th January 2016.

Estonia partners meeting, Rakvere, 27-29th January 2016.

Swedish partners meeting, Karlskoga, 3-4th March 2016.

German partners meeting, Gnashwitz, 8-10th March 2016.

UK partners meeting, Ashcott, 30th March 2016.

7th International Conference on Explosives Education and Certification of Skills (7th ICEECS)

The 7th ICEECS was held at QHotels Hotel and Golf Resort, Telford, on 14th April 2016.

Mr Johan Fingsteen Gjødvad, Immediate Past President of the European Federation of Explosives Engineers opened the conference with an insightful and passionate keynote speech supporting the drive for improvement of safety in the industry and the importance of common standards and measurement of competence.

Each of the industry partners gave a presentation on their part and experiences in the project, so far. The titles of the presentations were:

> EUExImp Project background and progress – Erik Nilsson, Project Leader, KCEM AB, Sweden
>
> "NOS as a management tool" – Stefan Krol, President of the Bofors Test Center, Sweden
>
> "The definition of the correct standards, the determination of the required qualification and the selection of the appropriate course…" – Jörg Rennert, Managing Director, Dresdner Sprengschule, Germany
>
> "Why occupational standards on ESA are important to Portuguese companies?" – José Gois, Assistant Professor, University of Coimbra, Portugal
>
> "Redeveloping the UK Explosives SFX Qualifications Framework" – Tom Goodman, Event Horizon, UK
>
> "The Step-by-Step Guide to implementing occupational standards" – Workshop led by Ken Cross, Director, PICRITE Ltd, UK

The workshop was considered extremely useful by the organisers due to the great interaction by the participants, whose input will be incorporated in the first publication of the Step by Step Guide.

The presentations will be published on the EUExcert website www.euexcert.org as they are released.

Outputs

The two 'intellectual outputs' (EC terminology) from the project are:

A step-by-step guide which will provide users with the mechanics of implementing the occupational standards. The first edition of the step by step guide is due to be published by KCEM AB on the EUExcert website in June 2016.

A more detailed manual which will provide more insight into the standards, the mechanics of implementation and case studies from the EUExImp project to provide examples of implementation in different parts of the explosives sector and in qualification attainment and management-tool modes. The manual is due to be published at the end of the project, in the summer of 2017.

Ken Cross MBE CEng MSc BSc(Hons) FIExpE
Chairman, EUExcert UK

A list of new IExpE Members:

Approval date 28th March 2016:

Philip Pantani
Adrian Kriening
Philip Bolton
Daniel Skelly
Kevin Meleady
Stephen Roberts
Andrew Maber-Jones
Jason Hogg

Approval date 15th April 2016:

Philip Halford
Michael Kehoe
Al Mukhida
Wagtail Limited (Company member)
Paul James
Mark Lewin
Kevin Bradley
Simon Hughes
David Spencer
Christopher Wilcock
Iain Smith

Approval date 9th May 2016:

Ian Higgins
Lee Phelan
John Gilbert
Yahaya Mohammed
Mark Kosack
Brett Chittick
Bryan Ford
Dean Simpson (upgrade to Fellow)
Alex Kenington
Herbert Feddon
Robert White
Steven Kelly
Andrew Ward
Jennifer Royal
Alan Morley (upgrade to Fellow)

Institute of Explosives Engineers
VOICE OF THE EXPLOSIVES INDUSTRIES

Registrar report

Professional Registration

Professional registration statistics as at 31st March 2016

	CEng	IEng	EngTech
QUALIFIED	24	5	3
IN PROGRESS	7	3	0

Application forms sent but not yet received back - 37.

Continuous Professional Development

The Institute published its requirement for professional registrants to conduct a minimum of 30 hours CPD per year. This CPD can take the form of meetings, seminars and events; the single important criterion is whether the individual has learned something from the activity. As such, the Institute has decided it does not need to issue attendance certificates but will support these if requested. Council takes the view that a professional explosives engineer will not breach their own integrity by not maintaining accurate CPD records. Notwithstanding that, the Engineering Council quality assurance policy for 2016 will require all institutions to undertake audits of registrants' CPD records and report back annually. Sample sizes and timelines have yet to be published.

Engineering Council

The Engineering Council is maintaining its continuing drive for the registration of Engineering Technicians. This is the first grade of professional registration and the Institute encourages those in their formative years in the industry, particularly those without university education to begin their progression through these professional grades as EngTech.

Monitoring and Audit

All registrants should be aware that the Engineering Council will monitor a percentage of CDP records from all Professional Engineering Institutions from January 17th. As a professional affiliate, IExpE will be required to sample our registrants' CPD and we are working with our partner licensed PEI on how this will be managed. Clearly there is more to follow but I can say at this stage that I am almost certain that records will need to be submitted through the mycareerpath software available from the website. This does not mean that you have to maintain your records in mycareerpath, especially if you are required to keep paper records, but if selected for monitoring, you will need a mycareerpath account in order to submit your records.

Mycareerpath

The mycareerpath management panel, in line with the Engineering Council's wider digitisation strategy, is committed to moving all member interactions with mycareerpath to an encrypted protocol(SSL). This entails leasing a secure signed certificate for each mycareerpath subdomain, and hence each institution. The initial and ongoing costs are expected to be rolled into the existing licence agreement at no additional cost to the institutions. The user grop affirmed its support for more secure access to the system by members and the EngC will contact institutions when work is ready to progress.

Special Registration Events

One of the new ways of working that we have been developing, in concert with QinetiQ, is the Special Registration Event. We intend to run a pilot event with QinetiQ at West Freugh on 7th June 2016 to test the concept. The idea is that we will give a presentation about the Institute and professional registration to a group of employees who work with explosive substances and articles, followed by Q&A and the opportunity to complete their membership application form and also start their professional registration application at the same time. The hope is that their membership application will be approved in good time and time gap between becoming a member of the Institute and their professional registration will be reduced by running the two processes in parallel.

Ken Cross MBE CEng MSc BSc(Hons) FIExpE
Registrar

Development Office for Explosives Skills (DOES) Programme Manager update

It was great to meet new IExpE members and friends at the IExpE AGM and conference, this was very well organised and well received by those present, the presentations were informative and enjoyable. I also continue to work with Sector Skills Strategy Group (SSSG) employers to plan site visits, CPD events and presentations (employer lead, DOES PM supporting/promoting) and these visits and events will be updated via the IExpE web pages.

I wish to pass on my sincere thanks to John Anderson, MD Weapons Division, QinetiQ for his professional stewardship and chairmanship of the SSSG over the last 4 years; it has been a pleasure and privilege to work with him and I wish him every success in the future. I wish to welcome Mark Hardman, MD Roxel Ltd who will be taking over the chairmanship of the SSSG and I look forward to working with him.

The SSSG employers continue to support the Early Careers Focus Group (ECFG) in the planning for the Early Careers in Weapons and Explosives Symposium (5th to 6th July, Heythrop Park in Oxfordshire) and will coincide with the next SSSG board meeting, so should encourage Director level attendance at the event. I wish to also pass on my personal thanks to Sian Slater, Chair of the ECFG for her professional support and enthusiasm over the last 12 months in taking forward the ECFG and wish her best wishes in her new employment. Contact for the ECFG is via email: earlycareerssymposium@gmail.com

The 2016 SSSG Ordnance, Munitions and Explosives Symposium will be held at the Defence Academy, Shrivenham on 1st to 2nd November 2016, the theme of the symposium will be "Technology Risk in Acquisition". This will include the risks associated with the use of energetic materials in weapon systems. If you wish to submit an abstract that you consider is also relevant to the overall theme, please email your abstract of around 200 words to caroline@symposiaatshrivenham.com

If any IExpE member has any questions, please feel free to contact me for details.

Allan Hinton FInstLM MCMI CMILT AIExpE
DOES Programme Manager

Email: doespm@iexpe.org or secretariat@iexpe.org
Mobile: 07866 429559 Tel: 01785 240154

The Explosives Industry Forum

When this edition of the Journal is published the Explosives Industry Forum (EIF) will have met on the 19th of May at HSE's Bootle offices and a report of that meeting will appear in September's edition.

Following January's meeting Dr Richard Daniels (HM Chief Inspector of Explosives) wrote to members of the EIF on the 31st of March to describes the outcomes of the review of the period of validity of Competent Authority Documents for fireworks that he had commissioned, provide an update on classification turnaround times and provide 'top tips' for complete applications for the classification of fireworks for transport.

Dr Daniels told the members of the EIF that some change is possible and that with immediate effect, all of the Competent Authority Documents (CAD) that HSE issues when it assigns or re-validates classifications for the transport of fireworks would now be valid for 10 years rather than the existing 5 years. This will benefit business by reducing the burdens on the sector from current arrangements.

He also told members of the EIF that HSE will continue to ask CAD holders to review the articles listed on CAD schedules as the CAD approaches the end of its period of validity. This is needed to verify that the assigned classifications for fireworks remain valid and in line with HSE's administration of the ADR requirements and specifically that:

- the data provided to HSE and used as the basis of the classification assignment has not changed;
- the manufacturer has not changed ; and
- any changes to Chapter 2.1 of ADR since the firework was originally classified have been considered ensuring the classification either:
    - remains as originally assigned; or
    - is changed to a different hazard division.

He said that HSE will continue to work with sector representatives to identify additional ways to improve the classification process and will also review with the sector how the information held on the classification status of individual fireworks can best be made available to manufacturers, importers, distributors, users and regulators.

Dr Daniels also informed EIF members of an analysis of the applications submitted to HSE for the classification of fireworks over the last 12 months to ensure that HSE was processing these as effectively as possible.

The analysis identified that when applicants provide all of the information necessary for completing an assignment with the application 92% of CADs are agreed within 20 working days and the average time to process an application to the point where the CAD is agreed is 12.5 days. Unfortunately only 46% of the applications HSE receive are accompanied at the outset by all of the information necessary to complete the classification assignment. This means that HSE have to seek further information from applicants which lengthens the process and means additional cost to the applicant.

Mr Adam's 'top tips' for complete applications for the classification of fireworks for transport are:

In general:

1. Ensure the English translation is provided on the drawings for all the components in the firework.
2. Ensure the compositional information is completed fully and the quantities are accurate e.g. in the tables on drawings.
3. Ensure the firework type is correctly identified and that the appropriate dimensions are provided – cross reference to the UN default table and HSE web-site.
4. If non-blackpowder compositions are used to produce an aural effects or as a bursting charge or lifting charge and are not to be considered 'flash composition', HSL Flash Composition Test data must be provided which shows the pressure rise time is greater than 6 ms.
5. Ensure that the spreadsheet and drawings match / are consistent with each other.

And additionally when the firework is packed in mitagatory packaging to:

Ensure the technical details of the mitigatory packaging is provided including external dimensions, thickness of wire, size of mesh and banding arrangements, preferably with an illustrative drawing. This information will be transferred to the front sheet of the CAD.

1. Ensure full series 6 test results(ie (a), (b) & (c)) are provided - due to the additional confinement provided by the mitigatory packaging.
2. Ensure the orientation of the packages when tested covers the worst case e.g. 5 sided mesh.
3. Where analogy is claimed against a tested item, information should be provided on a comparative basis for:
    - the total NEQ;
    - individual item NEQ; and
    - the % flash composition.

    All three of these should be less than the tested item

If you have any suggestions on additional ways to improve HSE's classification process or on how the information held on the classification status of individual fireworks can best be made available to manufacturers, importers, distributors, users and regulators please can you email the Secretariat on secretariat@iexpe.org or Council's Legal and Compliance Group on legislation@iexpe.org.

On the 8th of April HSE wrote to members of the EIF to update them on the progress that has been made regarding the initiation of the Fundamental Review of HSE's Approach to Explosives Licensing which has been included as a deliverable in HSE's business plan for 2016-17.

HSE are currently working to finalise membership of the project's governance group which will include Dave Welch, our President.

The principle areas of work that will be covered by the review are:

- Conducting a headline review of HSE's procedure for licensing (SPC/Permissioning/34) and the Guide to Applicants which it references;

- Reviewing existing application forms;
- Identifying the range of approaches that can be taken to determining the separation distances that appear on licences;
- Identifying whether there is a wider role for licences whose conditions are driven by a detailed assessment of likelihood rather than a generic assumption of likelihood;
- Identifying alternative formats for explosives licences to those currently in place to include consideration of the standard terms, explosives schedule and building schedule;
- Considering the period that HSE grants licences for;
- Considering HSE's role in the regulation of the storage of higher hazard explosives (HT1 & HT2);
- Considering HSE's role in the regulation of the 'fusing exemption' for fireworks present on licensed explosives sites; and
- Identifying those scenarios where HSE would expect to regulate the 'use' of explosives and other 'activities' on a licensed site by way of the licence.

Following on from the very effective engagement and significant contribution made by the wider sector to both the transposition of the recast of the Civil Use Explosives Directive and the Explosives Legislative Review, the review's project team will be 'taking over' the ELR Community and the ELR e-mail account ELR@hse.gsi.gov.uk following the coming into force of the Explosives Regulations 2014 (Amending) Regulations 2016 (http://www.hse.gov.uk/explosives/regulations2016.htm) on the 20th of April. Some of you will no doubt note the appropriateness of the existing acronym!

HSE will be using that community and e-mail account as its principle communication route and would be grateful if any correspondence on the review could be sent to the ELR e-mail account.

HSE plan to gather views from both representative organisations, such as the Institute, individual licensees and cross-sector groups such as the SSSG's topic groups. If you would like to contribute to the Institute's input to the review please can you email the Secretariat at secretariat@iexpe.org or Council's Legal and Compliance Group at legislation@iexpe.org with your views. If you want to make an individual response or suggestions on how HSE's licensing of explosives manufacture and storage can be improved you can contact the project team directly at ELR@hse.gsi.gov.uk.

EIF agendas, papers and minutes are available on HSE's Explosives Group Web Community at http://webcommunities.hse.gov.uk/connect.ti/explosives/grouphome

Martyn Sime BSc(Hons) PGDip MRSC CChem MIExpE
Email: legislation@iexpe.org

Journal Awards 2016

Have your paper/ article published in Explosives Engineering

Further your career, get noticed, promote novel work. Write on any explosive-related topic, papers/articles to be no more than 3500 words as a Word document.

Prizes provided by Explosives Engineering Educational and Research Trust. Winners selected by a panel of judges

Demonstrate your new ideas, forward vision, perception and innovation in a paper/article for publication in Explosives Engineering, the quarterly journal of The Institute of Explosives Engineers, supporting the professionals in the industry and promoting the explosives sector worldwide.

Possible themes but others considered:
Binary explosives
Blasting and mining
Demolition
Education and training (CPD)
Environmental concerns
Environmentally friendly munitions, disposal techniques
Explosives equipment and storage
Explosives in oil industry
Explosives manufacture
Fireworks and Special Effects
Health and Safety considerations
Insensitive munitions
Improvised explosive devices (IEDs) and their disposal
Pyrotechnic compositions
Site remediation
Underwater excavation

Four £500 cash prizes plus framed certificate each

Competition Prize Categories

- General public/Academics/Students/ Non-members of IExpE
- Associate/Technical Members of IExpE
- Members of IExpE
- Fellows of IExpE

Deadline for submission for the Journal Awards: 30th November 2016

Results published in Explosives Engineering: March 2017

Further information:www.iexpe.org

Large-scale explosive arena trials – is your target being loaded correctly?

By **Dr Thomas Payne** BSc MSc PhD, **Andrew Williams** CEng MICE MCIOB AIExpE,
Thomas Worfolk BEng AMIET and **Dr Samuel Rigby** MEng PhD MIExpE

Introduction

Internationally, a substantial body of experimental testing has been conducted to assess the performance of glazing and other structural components, such as walls and doors, under blast loading. This often takes place in large-scale arena tests and involves setting up numerous targets at different ranges around a central charge. This setup is employed to maximise the usable arena space in each shot, thereby improving cost-efficiency and helping to achieve 'best value'.

Overall, arena test charge sizes can vary from 10s of kg to 10s of tonnes, but the most common charge sizes in UK testing are in the 100s of kg range, all measured in TNT equivalence (TNT$_e$).

UK arena testing of glazing commonly follows the general principles of *ISO16933:2007 Glass in Building – Explosion-resistant Security Glazing – Test and Classification for Arena Air-blast Loading*. Glazing targets are commonly 1.25 x 1.55 m in size and are typically mounted in cubicles; either 2.4 m wide x 2.4 m high front-face dimensions with a single landscape aperture, or 3.2 m wide x 3.15 m high front-face dimensions with twin portrait apertures, as shown in Figure 1.

UK arena testing of walls and doors commonly follows *21/09 Home Office Test Standard for Protected Spaces (Explosion Resistant Walls and Doors)*. Wall targets are commonly constructed up to 3.0 m wide x 3.5 m high and mounted within a cubicle formed from reinforced concrete culvert units 3.45 m wide x 3.9 m high, as shown in Figure 1.

Figure 1. Typical glazing targets mounted in a single aperture cubicle and a double aperture cubicle, and a typical wall target mounted in a reinforced concrete cubicle (courtesy of DNV GL).

The actual blast loading imposed on the targets during testing is generally measured using a reinforced concrete gauge block of a similar size to the target, positioned at a matching range and with pressure transducers mounted in appropriate locations, flush with the face of the gauge block.

By assuming a hemispherical blast front, one can infer identical loadings on targets of the same size located at the same range as well as on appropriately-sized and located gauge blocks.

However, problems may occur where targets are placed too close together and blast load interactions with individual targets begin to interfere with the loading experienced by other neighbouring targets.

Aside from experimental testing, predicted loadings can also be derived using suitably validated software codes. This study uses one such code to assess the influence of target placement on the blast loading experienced.

Blast wave interaction

When a blast wave hits a target of finite size, it reflects from it and diffracts around it, modifying the pressure-time histories of nearby waves. Reflections can result in an amplification effect through a superposition with the incident blast wave (see Figure 2a). Diffractions can result in a shielding (or shadowing) effect decreasing the intensity of the blast wave, such as in the region behind the structure (Remennikov and Rose, 2005; Needham, 2009) (see Figure 2b).

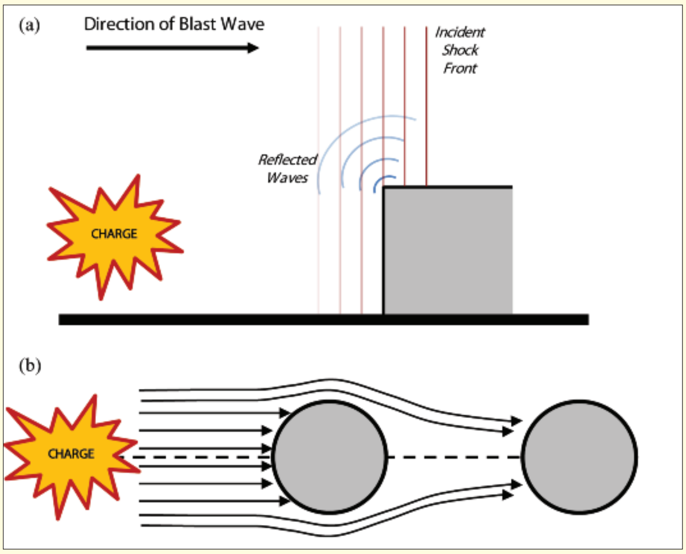


Figure 2. Schematic showing formation of: (a) an amplification effect and (b) a shielding effect.

Previous research investigating the interactions of blast waves with structures has focused largely on the local 'clearing' effects experienced by structures of finite size when exposed to a blast wave (Rickman and Murrell, 2007; Shi *et al.*, 2007; Ballantyne *et al.*, 2009; Qasrawi *et al.*, 2015). Recent studies have led to new perspectives on the mechanisms for the clearing effect and proposed methods to calculate their extent (Rigby *et al.*, 2014a).

In terms of blast wave interference, a growing body of research has been conducted investigating blast loadings in urban streetscape environments. Early work conducted by Smith and Rose (2000) investigated the features of urban streetscape environments that amplify blast effects using experimental study and computational fluid dynamics (CFD) software. Remennikov and Rose (2005) subsequently conducted a detailed series of numerical simulations using Air3D CFD software to investigate shadowing and amplification effects from buildings in an urban terrain. In recent years, a significant focus has been placed upon internal explosions and different building geometries.

However, to the authors' knowledge, there are no research studies investigating the specific interferences introduced due to the proximity of neighbouring structures in arena blast trials.

Pressure and impulse are widely acknowledged to be the two key contributory factors relating to blast load damage on structures. Although the negative phase has been shown to be influential in blast damage, particularly in more frangible structures (Rigby *et al.*, 2014b), this study focuses on rigid targets and these effects have been neglected.

To achieve 'best value' in testing it is beneficial to include as many targets as possible within each arena. In practice, two engineering 'rules of thumb' are typically used as a guideline for engineers in the field to ensure that individual targets do not adversely influence the blast loading on other adjacent or nearby targets.

- *For two cubicle targets at the same stand-off range*: a minimum separation of two cubicle widths between the targets.
- *For two cubicle targets at different stand-off ranges:* a minimum angle of 45° between the centreline of the targets measured from the detonation point.

Examination of the interference effects of the positive phase loading phenomena from rigid target obstructions will enable more informed cubicle placement in arena blast trials. Such information could also be used to confirm the veracity of these engineering rules of thumb and potentially permit a greater number of cubicle targets to be positioned around a charge, thus increasing efficiency and reducing costs.

The following two photographs show a typical arena test setup before (Figure 3) and during (Figure 4) a test.

Figure 3. General view of a typical arena test setup (courtesy of DNV GL).

Figure 4. General view of a typical arena test in progress (courtesy of DNV GL).

This study aims to use conventional numerical modelling techniques to examine the influence of cubicle positioning in large-scale arena blast trials and present a series of recommendations for placement in a format that can easily be used by engineers in the field.

Methodology

Modelling software and approach

CFD software package Air3D (Cranfield University, UK) (Rose, 2006) was used for all simulations in this study as the software provided a verified level of blast wave fidelity and phenomenology whilst possessing a relatively low computational expenditure.

The software requires the following assumptions for any scenario:

- the ground surface and targets are considered perfectly rigid;
- the impacts of thermal shocking and detonation products are ignored;
- air and other gaseous products are treated as ideal; and
- the blast wave is assumed to be spherical/hemispherical.

To determine the influence of arena test cubicles on nearby blast waves, a series of paired simulations were run: one free-field and the other with a single obstructing cubicle target present. The differences in incident overpressure-time histories were then examined between free-field and obstructed-field simulations to identify the degree of interference in peak incident overpressure (Ps^+) and incident positive phase impulse (Is^+) from each test configuration.

In each simulation:

- The target cubicle (in obstructed-field simulations only) was fixed at a range of between 15 and 50 m in 5 m intervals.
- The cubicle was given dimensions of 3.50 m x 3.95 m x 3.00 m (width x height x depth), representative of a typical wall target.
- Arrays of pressure gauges were distributed radially in an arc from the explosive source, each array contained a total of 400 gauges evenly distributed over the region of interest at a height of 2.00 m (approximately half the cubicle height).
- The gauge arcs were positioned in 5 m stand-off intervals from the target (i.e. a 35 m stand-off target would have gauges on arcs at 35 m, 40 m, 45 m and 50 m stand-off ranges).
- A 100 kg TNT$_e$ charge (using Air3D default TNT charge parameters) was used.

An example 2D schematic of the test configuration has been shown in Figure 5.

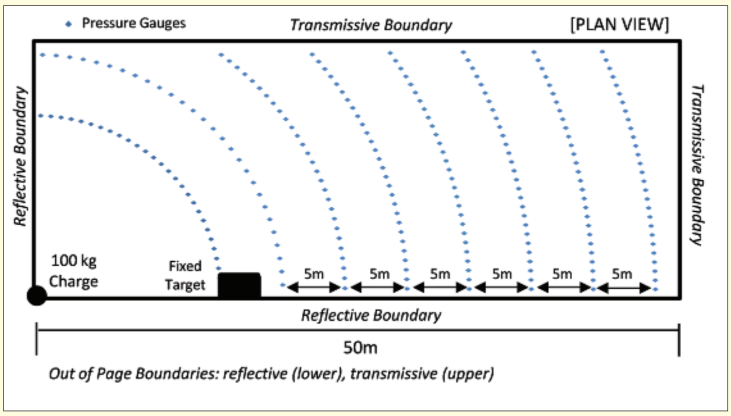


Figure 5. Schematic of simulation test configuration.

Model development and software validation

In Air3D, explosive simulations are treated in a multi-stage process through 1D, 2D and 3D domains. In the 1D domain, the simulation is performed to model the formation of the wave up to the nearest surface, in this case the ground. As it reaches this first surface it ceases to be spherically symmetric. The solution is remapped into 2D with a reflective ground surface and an axisymmetric simulation is run that models blast wave formation and propagation up to the point where it interacts with the second surface, in this case the target structure. Once it reaches this second surface it is no longer axisymmetric and the solution is remapped to a 3D domain, where the interaction between the blast wave and the structural target is simulated.

The Air3D version 9.0 users' guide (Rose, 2006) states that "Problems should be set up initially using a discretisation that allows an accurate description of the problem geometry and captures all major aspects of the flow-field: correct number and duration of shock waves". Mesh refinements were therefore conducted in all domains to ensure that blast phenomena were adequately represented, balancing accuracy and computational cost.

A series of iterative mesh refinement simulations informed the use of 1 mm and 20 mm cell sizes for 1D and 2D simulations respectively. 3D mesh refinement simulations were compared with CONWEP (US Army Corps of Engineers, Engineer Research and Development Centre) hemispherical burst parameters to provide a measure of the absolute accuracy of the predictions (Figure 6). This convergence study demonstrated a 3D cell size of 100 mm delivered a reasonable level of accuracy relative to computational costs.

The Air3D software output was further validated by conducting separate, blind predictions of a set of experimental blast trials conducted at the University of Sheffield (Tyas et al., 2011). The experiments investigated clearing effects using a 250 g C4 hemispherical explosive charge against a 675 x 710 mm rigid target at ranges of 4-10 m.

Figure 7 shows a comparison between the pressure-time histories and cumulative impulse-time histories from the experimental test data and the Air3D predictions for the gauge located centrally in the target face.

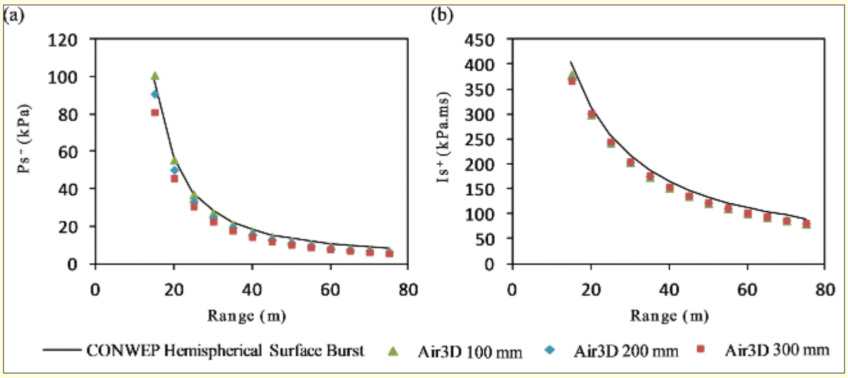
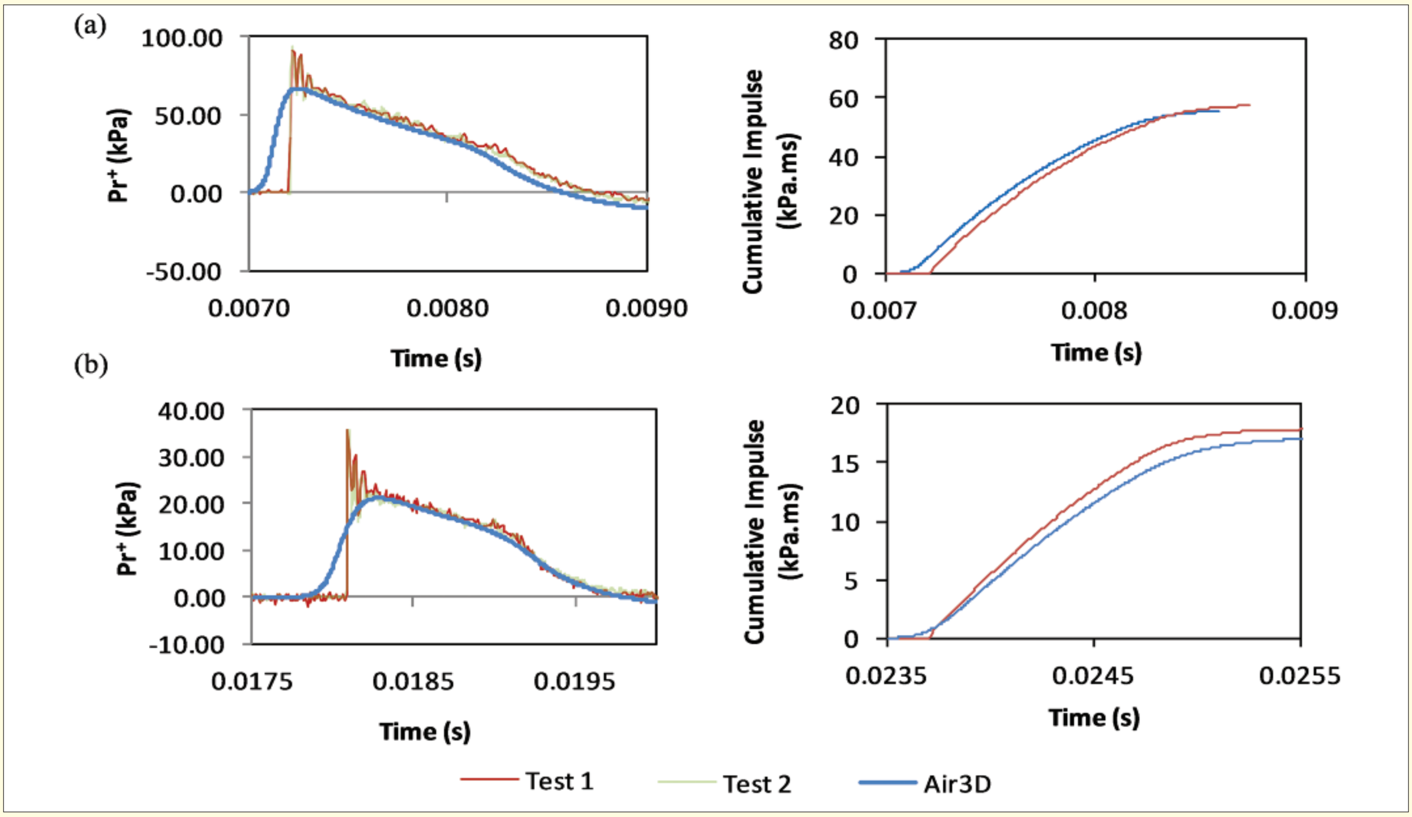


Figure 6. Comparison of Ps^+ and Is^+ of different cell size simulations against CONWEP hemispherical burst predictions.

Figure 7. Comparison between Air3D predictions and experimental test data (Tyas *et al.*, 2011) for targets at: (a) 4 m and (b) 10 m ranges.



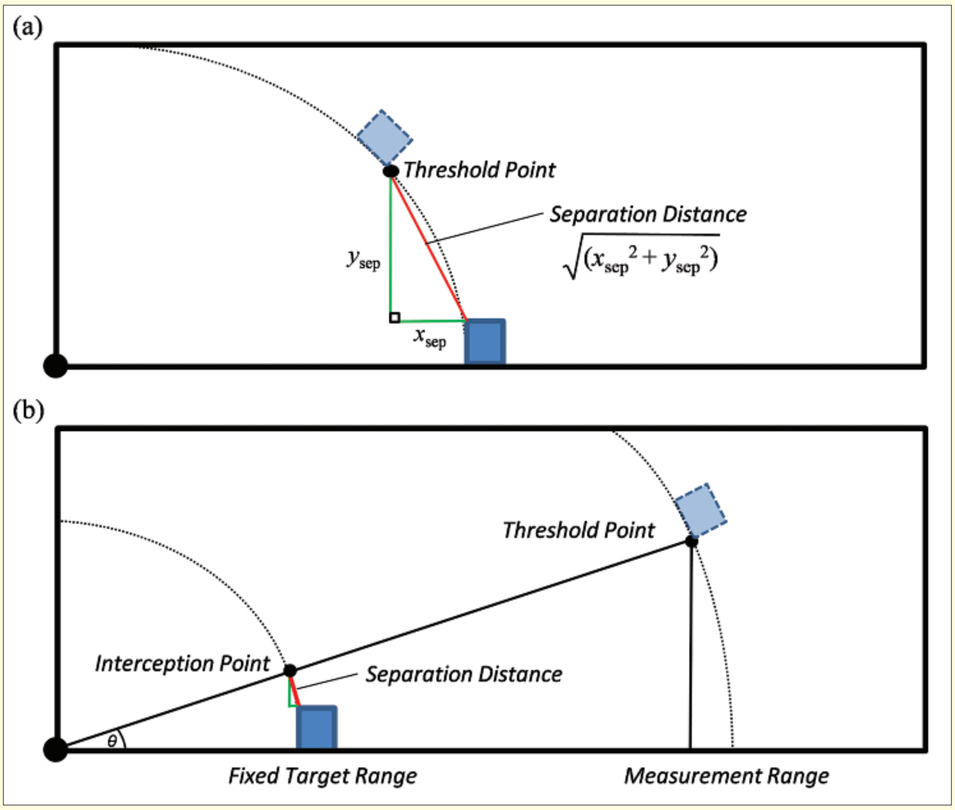


Figure 8. Schematic showing the calculations performed to determine minimum separation distances at different interference thresholds when the fixed target and measurement positions are at: (a) the same stand-off range; and (b) different stand-off ranges.

These comparisons demonstrate an acceptable level of accuracy for predicted pressure-time histories. The predictions for peak reflected, positive phase impulse (Ir^+) values were found to match the mean experimental values to within 3%.

Post-processing

Given the significant quantities of data produced by the arrays of pressure gauges, MATLAB® (Mathworks Ltd., MA, USA) was selected as the post-processing tool due to its robust and efficient processing capabilities.

In each simulation, the pressure-time histories extracted from Air3D were imported into MATLAB® and processed to determine Ps^+ and Is^+ values. The array of Ps^+ and Is^+ values from the free-field simulations were then processed alongside the corresponding values from the obstructed-field simulations to calculate the percentage difference (or interference) at each gauge position. Given an array of percentage difference values for Ps^+ and Is^+, a threshold value could be applied and the corresponding Cartesian co-ordinate location could be identified.

For instances where the fixed target and measurement location were at the same stand-off range from the charge, the straight line distance between the edge of the fixed target and the threshold co-ordinate was determined using simple Pythagoras (Figure 8a). For instances where the fixed target was at a different range to the measurement location, the straight line separation from the fixed target at the same range was calculated. To achieve this, the equation of the line from the threshold point to the origin was calculated and used to determine the intersection with the fixed target gauge arc (Figure 8b). This point was then, in turn, used to calculate the straight line distance to the fixed target edge and the corresponding value of θ.

Results

General trends

The visualisations in Figure 9 (see over page) show, in plan view, an example of peak incident overpressure (Ps^+) and incident positive phase impulse (Is^+) interference fields around a fixed target cubicle positioned at a 15 m stand-off range recorded at approximately 2 m above ground level.

Figure 9a and Figure 9c show plan views (in half symmetry) of the Ps^+ and Is^+ interference fields respectively around a fixed target cubicle positioned at a 15 m stand-off range.

Figure 9b and Figure 9d show the calculated percentage difference between the interference fields above and the associated free-field measurements expected within the domain, for Ps^+ and Is^+ respectively.

It is evident that there are differences in the magnitudes of effects of Ps^+ and Is^+ and the regions affected by the target. It is also clear that there are significantly greater differences in Ps^+ than Is^+ in the immediate proximity to the fixed target.

Figure 10 (see over page) shows the radial distances from the fixed target to the position of maximum interference and limit of interference (free-field equivalent position) for Ps^+ and Is^+. In all cases, the maximum interference and the limit of interference in Ps^+ occurs at much closer proximity to the target than Is^+.

Assuming the relationship to be linear, the critical angles for maximum interference and limit of interference were 21.7° and 35.7° in Ps^+ respectively, and, 39.7° and 44.6° in Is^+ respectively. From these values, the angle for 'limit of interference' in Is^+ appears to correspond well with the 45° recommended in established rules of thumb.

Recommended separation distances

As greater separation distances were required to elicit free-field equivalent Is^+ values than Ps^+ values, impulse predictions have been used to derive a series of recommended separation distances for cubicle targets in blast testing arenas. Note that the values in this table represent the separation distances required at the same range as the fixed target and, where necessary, should be used to infer target position at greater stand-off distances via the method shown in Figure 8b as the angle of the 'limit of interference' has been shown to be effectively constant with increasing distance from the explosive origin as in Figure 10 (See over page).

Table 1, (see over page), presents the recommended separation distances to achieve '0% threshold', or free-field equivalent Ps^+ and Is^+ values for targets at a stand-off range between 15 and 50 m. It also gives the recommended separation distance to achieve '2% Threshold' and '5% Threshold' values.

The terms 'fixed target location' and 'variable target location' in this table pertain to the method by which cubicles should be positioned. The fixed target is considered stationary with the variable target positioned relative to it.

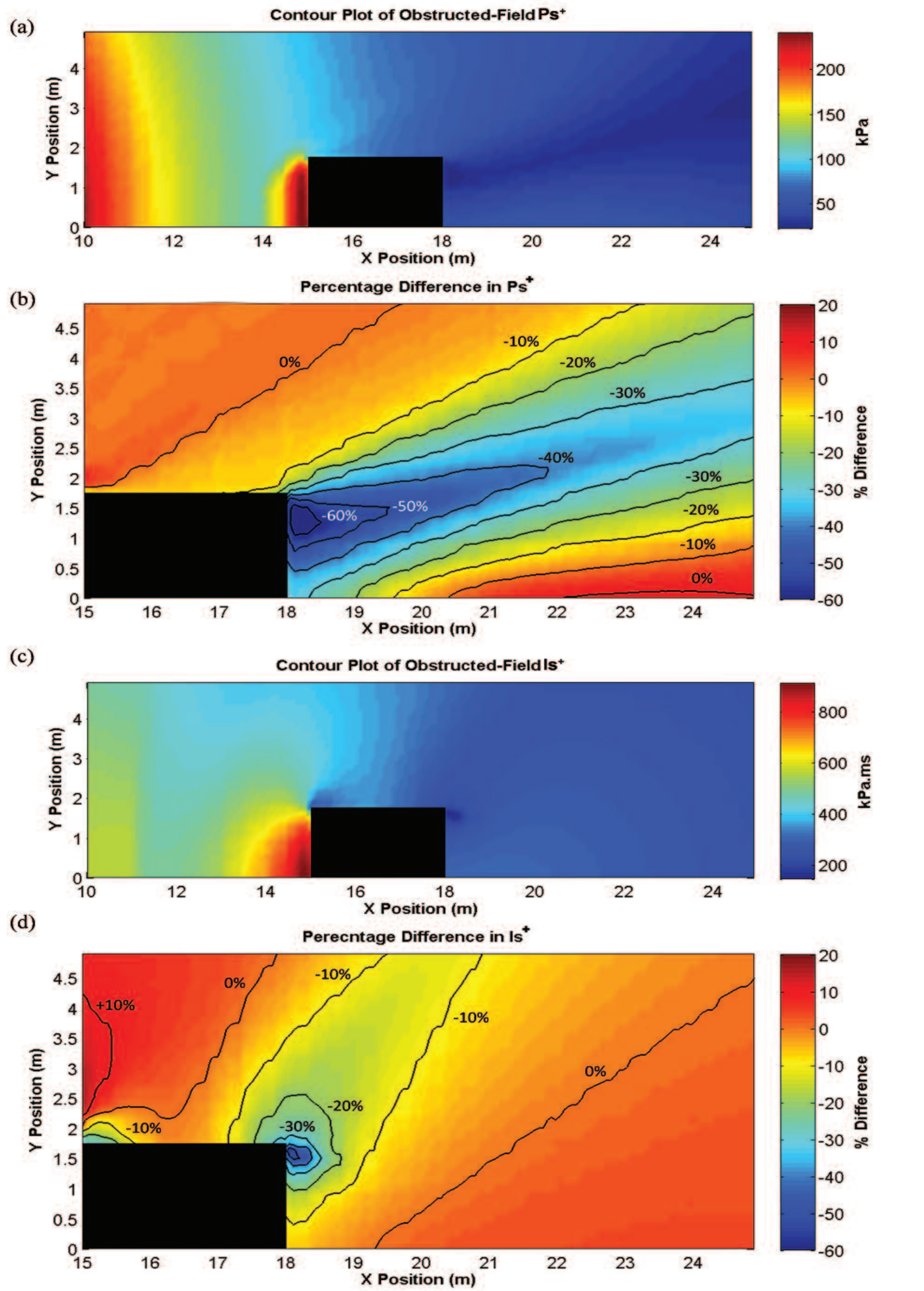


Figure 9. Visualisations of interference by a fixed target obstacle at 15 m. Contour plots show examples of: (a) obstructed-field Ps+; (b) percentage differences in Ps+; (c) obstructed-field Is+; and (d) percentage difference in Is+.

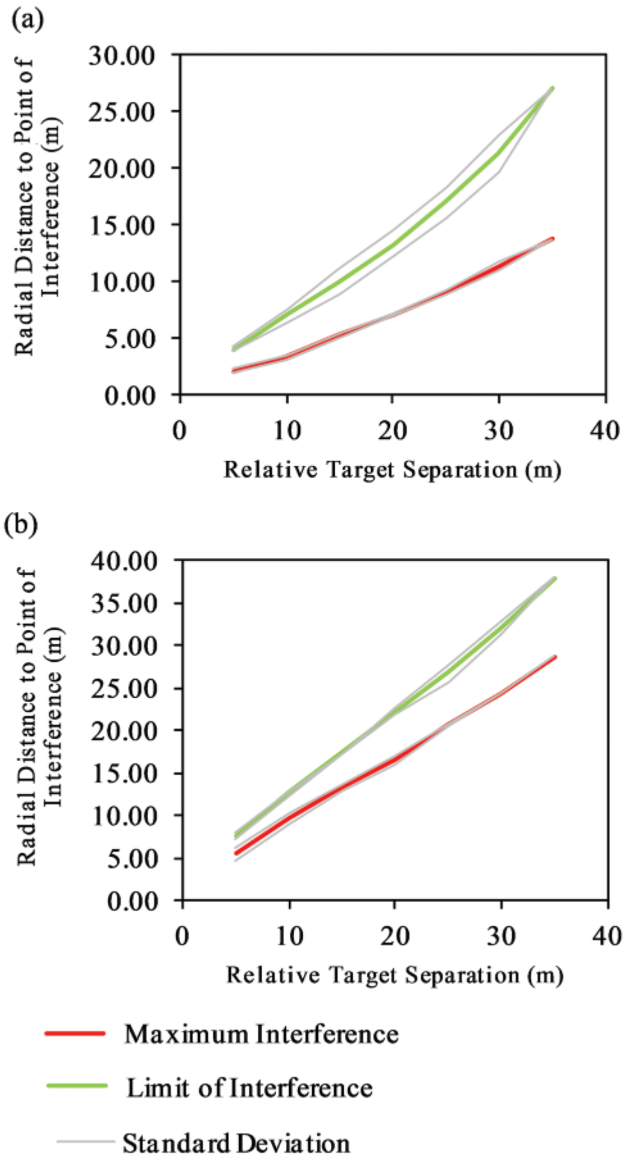


Figure 10. Graphs showing the levels of interference introduced by fixed target obstacles at different relative target separations for: (a) Ps⁺; and (b) Is⁺.

2% Threshold (Recommended Separation Distances)

Fixed Target Location \ Variable Target Location	15 m	20 m	25 m	30 m	35 m	40 m	45 m	50 m
15 m	3.69	3.01	5.03	6.17	7.05	7.64	8.11	8.51
20 m		4.23	3.43	5.77	7.15	8.38	8.87	9.46
25 m			4.59	3.90	6.39	7.94	9.24	9.46
30 m				5.03	4.20	6.89	8.68	9.72
35 m					5.48	4.49	7.28	9.02
40 m						5.57	4.78	7.57
45 m							5.70	5.03
50 m								6.02

0% Threshold (Recommended Separation Distances)

Fixed Target Location \ Variable Target Location	15 m	20 m	25 m	30 m	35 m	40 m	45 m	50 m
15 m	3.88	3.30	5.55	6.88	7.96	8.70	9.21	9.64
20 m		4.58	4.03	6.49	8.08	9.50	10.1	10.7
25 m			5.03	4.51	7.18	8.97	10.5	10.9
30 m				5.26	4.72	7.87	9.87	11.2
35 m					5.58	5.42	8.32	10.3
40 m						5.99	5.48	12.1
45 m							6.87	5.83
50 m								6.92

5% Threshold (Recommended Separation Distances)

Fixed Target Location \ Variable Target Location	15 m	20 m	25 m	30 m	35 m	40 m	45 m	50 m
15 m	3.20	2.53	4.32	5.36	6.02	6.50	6.87	7.16
20 m		3.58	2.93	4.93	6.02	7.20		
25 m			3.90	3.28	5.34	6.52	7.69	
30 m				4.05	3.53	5.62	7.27	
35 m					4.20	3.79		
40 m						4.48	3.88	
45 m							4.69	4.01
50 m								4.78

Table 1.Recommended clear separation distances to achieve representative (0% interference) free-field Ps⁺ and Is⁺ values, 2% interference values and 5% interference values for fixed and variable targets at different stand-off ranges.

Recommended separation distance tables can be established for any given percentage interference value through further processing of the existing results dataset.

Note that in some instances, at greater interference thresholds, separation distances have not been quoted. This is because, for that specific location, the obstructed-field Is⁺ value does not deviate from the free-field value by more than the relevant percentage threshold.

Discussion

This study provided a series of recommendations for cubicle positioning in arena blast trials through the determination of the differences in free-field pressure-time histories, with and without an obstructing target present, using numerical modelling techniques. In all conditions, there was a greater interference to peak incident overpressure (Ps⁺) values than to incident positive phase impulse (Is⁺) values in the region immediately surrounding the fixed target. However, Ps⁺ values were found to return to free-field equivalents relatively close to the target, whilst Is^+ values remained significant at greater distances. Consequently, Is^+ interferences governed the separation distance recommendations.

To examine the appropriateness of the existing engineering rules of thumb typically used as a guideline for engineers in the field, a direct comparison has been made with the new recommendations.

In these existing rules of thumb, for targets at the same range and assuming a wall target of 3.50 m width, a practical recommendation of 7 m is given (two cubicle widths). The recommendations from the present study vary between 3.88 m and 6.92 m based on target range. This suggests that the rule of thumb is of a similar magnitude to predictions in far-field conditions, but conservative for targets in the near field where a smaller separation could be applied and more targets could potentially be distributed around the charge.

The minimum separation angle of 45° corresponds very well with the angle for the limit of Is^+ interference of 44.6° established in this study. However, it should be noted that these measures are not directly comparable and the angles illustrated in Figure 10 have been based on an average taken from many simulations with different fixed target ranges and measurement positions (but the same relative separation). Therefore, it is likely that there will be variations based on individual test configurations. Although 45° acts as a reasonable estimate, there will be many situations where this rule of thumb will not be appropriate and the table recommendation distances should take precedence over the established rules of thumb.

Conclusions

In arena blast tests, a lack of careful consideration of the positioning of target cubicles around a charge can result in either: sparsely distributed targets, which poorly utilise test range space; or targets positioned too closely together, which can result in undesirable interference effects by either increasing or decreasing incident blast wave parameters.

An extensive and systematic modelling study was undertaken using Air3D to identify the differences in peak incident overpressure and incident positive phase impulse caused by a fixed target obstruction. The study indicated that, in all conditions, a greater separation distance was required to achieve free-field impulse values than free-field pressure. A bespoke series of recommendation tables has been presented for different permissible interference thresholds, which can be used by engineers in the field to identify minimum separation distances for targets at different ranges.

The results indicate that the established 'rules of thumb' for separation of targets at different ranges (45°) still hold some practical relevance, whilst the recommendation for targets at the same range (two cubicle widths) are generally conservative and not applicable to all test configurations.

References

Ballantyne, G. J., Whittaker, A. S., Dargush, G. F. and Aref, A. J. (2009) 'Air-blast effects on structural shapes of finite width', *Journal of Structural Engineering*, 136 (2), pp 152–159.

Needham, C. E. (2009) 'Blast loads and propagation around and over a building', 26th *International Symposium on Shock Waves*, Volume 2, pp 1359–1364. Springer Berlin Heidelberg.

Home Office Science (2010) 'Test Standard for Protected Spaces (Explosion Resistant Walls and Doors)', Home Office Scientific Development Branch, Publication No. 21/09

ISO 16933:2007(E) (2007) 'Glass in Building – Explosion-resistant Security Glazing – Test and Classification for Arena Air-blast Loading', International Organisation for Standardisation, Geneva, Switzerland

Qasrawi, Y., Heffernan, P. J. and Fam, A. (2015) 'Numerical Determination of Equivalent Reflected Blast Parameters Acting on Circular Cross Sections', *International Journal of Protective Structures*, 6 (1), pp 1–22.

Remennikov, A. M. and Rose, T. A. (2005) 'Modelling blast loads on buildings in complex city geometries', *Computers and Structures*, 83 (27), pp 2197–2205.

Rickman, D. D. and Murrell, D. W. (2007) 'Development of an improved methodology for predicting airblast pressure relief on a directly loaded wall', *Journal of Pressure Vessel Technology*, 129 (1), pp 195–204.

Rigby, S., Tyas, A., Bennett, T., Fay, S., Clarke, S. and Warren, J. (2014a) 'A numerical investigation of blast loading and clearing on small targets', *International Journal of Protective Structures*, 5 (3), pp 253–274.

Rigby, S., Tyas, A., Bennett, T., Clarke, S. and Fay, S. (2014b) 'The negative phase of the blast load', *International Journal of Protective Structures*, 5 (1), pp 1–20.

Rose, T. A. (2006) 'A Computational Tool for Airblast Calculations', *Air3d version 9 users' guide*. UK: Cranfield University.

Shi, Y., Hao, H. and Li, Z. X. (2007) 'Numerical simulation of blast wave interaction with structure columns', *Shock Waves*, 17 (1–2), pp 113–133.

Smith, P. D. and Rose, T. A. (2000) 'The influence of urban geometry on blast wave resultants', *Proceedings of the 16th Military Aspects of Blast and Shock Symposium*, vol. 10, p. 15. UK: Oxford.

Tyas, A., Warren, J. A., Bennett, T. and Fay, S. (2011) 'Prediction of clearing effects in far-field blast loading of finite targets', *Shock Waves*, 21 (2), pp 111–119.

Acknowledgements

The analysis on which this paper is based was conducted as part of an ongoing programme of research and development, funded and directed by the Centre for the Protection of National Infrastructure (CPNI).

All photographs in this paper were taken at DNV GL Spadeadam Testing and Research located at RAF Spadeadam in Cumbria by the Home Office Centre for Applied Science and Technology.

Thomas Payne, Andrew Williams and Thomas Worfolk are all at the Home Office Centre for Applied Science and Technology, Horsham, West Sussex and Samuel Rigby is at the Department of Civil and Structural Engineering, University of Sheffield.

Further information: Andy.Williams@homeoffice.gsi.gov.uk

Solving the SS Richard Montgomery problem with innovation and collaboration

The SS Richard Montgomery was wrecked in the Thames Estuary in 1944, with munitions making up 1,400 tons of explosive still on board. Over the years considerable work has been conducted to assess the threat it poses and how it should ultimately be dealt with. The longer it remains in place, the more difficult it will be to accurately identify and understand the risks from implementing a future course of action that may reduce or remove the hazard that it poses. The current wreck management strategy of non-interference requires re-evaluation to ensure the safety risk to the public is minimised.

On behalf of the UK Department for Transport (DfT), Dstl and Frazer-Nash assembled a Munitions Working Group (MWG) of Subject Matter Experts (SMEs) in 2015, including SDE Ltd, OTS Ltd, Cranfield University and QinetiQ Ltd to investigate this problem. The MWG continues to deliver an innovative work package to analyse different wreck management strategies and provide an associated probability of mass detonation.

SS Richard Montgomery with the 3 masts showing above the waterline.

By **David Wyse** MEng MInstRE MIET and **Rob Leary** MSc MIMechE MIExpE MIIRSM

Background

The SS Richard Montgomery was a US liberty ship built in 1943 by St John's River Ship Building Company, Jacksonville, Florida. In August 1944, two months after the D-Day landings, the ship sailed from the USA bound for the UK and then France, carrying a cargo of various aircraft munitions of US design, totalling approximately 7,000 tons. On arrival, it was anchored in the Thames estuary. At the height of a spring tide on 20th August 1944 the ship's anchor dragged and she drifted onto the Sheerness Middle Sands (Little Nore) approximately 200m north of the Medway Channel. The vessel grounded amidships on the crest of the bank, initially resulting in hogging and the hull plates forward of the bridge beginning to split[1].

A cargo salvaging operation began three days after the initial stranding. The larger part of the munitions carried were removed from the holds until, after 11 days, the vessel flooded forwards in a gale and sank, resulting in it breaking its back. The removal effort succeeded in fully emptying hold numbers 4 and 5 of explosive cargo and partially emptied holds 1, 2 and 3. Approximately 1,400 tons net explosive quantity (NEQ) remains in the forward section[3]. The two sections, forward and aft, now lie in 15 metres of water with the masts protruding at all states of the tide.

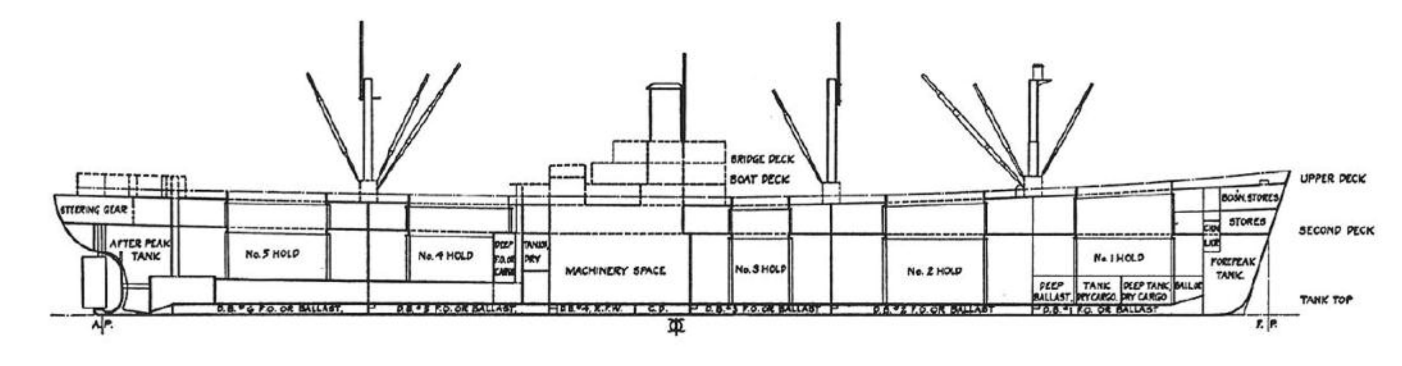


Figure 1. Liberty-class cargo vessel[2]..

The wreck of the SS Richard Montgomery is designated as a dangerous wreck under Section 2 of the UK Protection of Wrecks Act 1973. There is a prohibited area around the wreck and it is an offence to enter this area without the written permission of the UK Secretary of State for Transport. The wreck is clearly marked on the relevant Admiralty charts, the prohibited area around the wreck is ringed with four cardinal buoys and twelve red danger buoys, and the wreck is under 24-hour surveillance by Medway Ports under contract to the Maritime and Coastguard Agency[4].

The SS Richard Montgomery is predominantly of steel construction that will corrode over time, eventually resulting in structural collapse or loss of containment; the former being of interest to this study in particular, given the associated threat posed to the munitions on board the wreck.

Current Situation

The SS Richard Montgomery lies between two busy shipping lanes that lead to the major container handling facilities at Thamesport on the Isle of Grain, and London Gateway Port in the Thames. The Kent coastal town of Sheerness lies to the south, and Southend in Essex to the north. The east side of the Isle of Grain, closest to the wreck, is also home to Grain Power Station, a liquefied natural gas (LNG) terminal and a decommissioned oil refinery. Mass detonation of the munitions on board the wreck thus presents a significant danger to life, national infrastructure and private property.

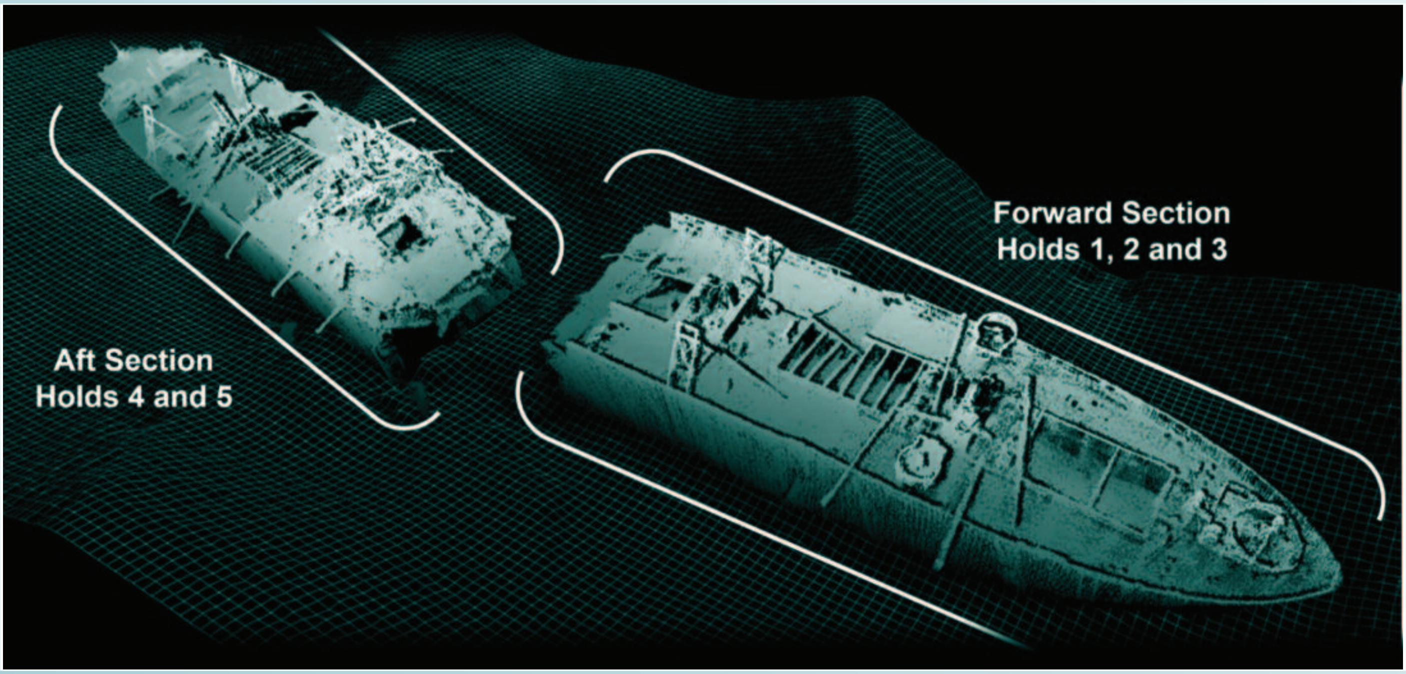
As part of the non-intervention strategy currently in place, a sonar survey of the wreck is carried out each year, with a detailed diver survey completed every ten years. The last diver survey was completed in 2013[4] and the last published sonar survey in 2014[5]. There is evidence that the structure of the wreck is deteriorating, but estimates of its remaining life before major structural failure occurs need to be further refined in order to better understand the risks involved.

A summary of the munitions believed to be on board and their locations within the forward section is shown in Table 1. The condition, sensitivity and explosive power of the munitions after more than 70 years on the sea bed is not known.

Requirement

In support of the overall objective of enabling the DfT to make informed decisions regarding how best to manage the SS Richard Montgomery, the question 'what is the probability of mass detonation of the munitions' was posed to Dstl. This was to be examined over a range of timescales (now, in 10 years' and 30 years' time) and against a number of courses of action (do nothing, conventional removal of the munitions, lift and shift the wreck as one, or bund the wreck and infill it in situ).

Figure 2. SS Richard Montgomery sonar scan 2013.



Hold	Munitions	Quantity	Filling	NEQ (tons)
1	Pyrotechnic signals	79 cases	Pyro	2
	Smoke bombs, 100 lb WP	1429 cases	WP	65
	'Clusters' (pyrotechnic device) and signals	256 boxes	Pyro	31
	Signals	560 boxes	Pyro	-
	Bomb 250 lb TNT AN-M57	1500	TNT	84
	Bomb 500 lb TNT AN-M64A1	1407	TNT	167
	Bomb 1000 lb TNT AN-M65	850	TNT	208
2	Bomb SAP 500 lb AN-M58	574	Amatol	41
	Bomb SAP 1000 lb TNT AN-M59	1068	TNT	140
	Bomb GP 2000 lb TNT AN-M66	286	TNT	144
	Bomb GP 1000 lb TNT AN-M65	588	TNT	140
	B260 lb fragmentation bomb M81	521-580	Comp B	9
	Fragmentation bomb clusters:	5297 cases	-	9
	AN-M1A1 6x20 lb (fuzed)		TNT	-
	And/or AN-M4A1 3x23 lb (unfuzed)		TNT	-
	And/or AN-M81 B260 lb		Comp B	-
3	Bomb SAP 1000 lb M59	1170	TNT	163
	Bomb GP 1000 lb M65	406	TNT	99
	Bomb SAP 500 lb M58	1351	Amatol	97
	Fuzes	~250 boxes	-	-

Table 1 - Munitions believed to be on board the SS Richard Montgomery and their location.

Approach

Through the collaboration of Dstl with five other industry experts and academic partners, a Munitions Working Group (MWG) was established in 2015 to establish a methodology for determining the probability of mass detonation. 'Mass detonation' was defined as the detonation of more than 90% of the munitions in any of the three holds. How a detonation would communicate and propagate to other holds would also be examined.

Previous studies over the years[1, 2] have considered the risks from the munitions on board the wreck; however the discussion and conclusions within these reviews were based on assumptions that may, or may not, be valid. In addition the focus of assessment for the risks varied across the reviews. Consequently there was insufficient evidence to support a claim that all reasonably foreseeable risks had been identified and that the associated assessments were reasonably defensible. Therefore an innovative new method of systematically identifying all of the risks was required.

Bow-Tie Diagrams

Bow-tie diagrams are typically used to support the visualisation of accident sequences, and assessment of associated risk through analysis of the effectiveness of barriers to progression of the accident sequence. The power of a bow-tie diagram is that it gives an overview of multiple plausible scenarios, in a single picture. It provides a simple visual explanation of a risk that may be much more difficult to explain otherwise. A generic bow-tie diagram is shown in Figure 3.

A bow-tie diagram considers the following elements:

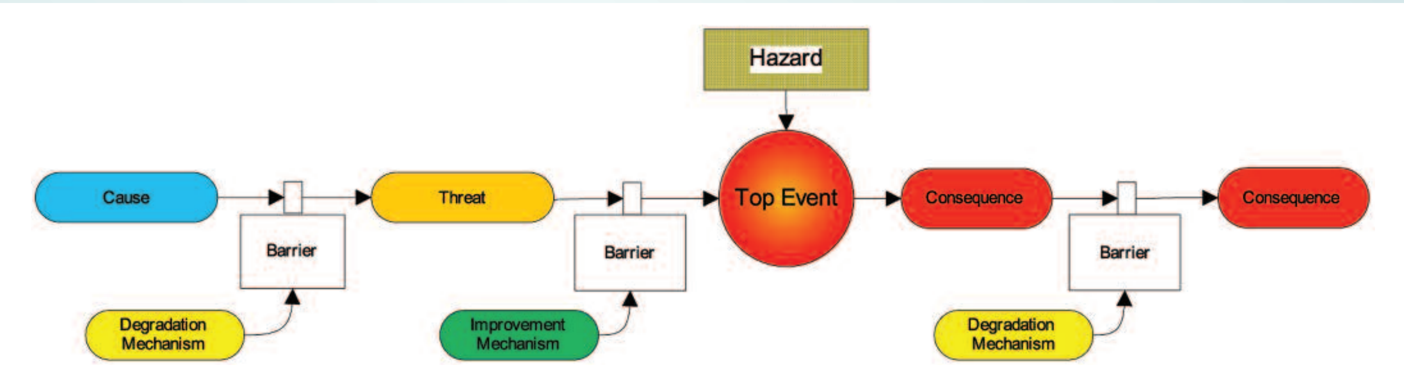
- Cause - the source of a threat
- Threat - an event that may cause the top event to occur
- Barrier - a control, or characteristic of the system under consideration, that prevents progression of the accident sequence
- Degradation mechanism - a cause of reduction of the effectiveness of a barrier
- Improvement mechanism - a cause of enhancement of the effectiveness of a barrier
- Hazard - something which has the potential to cause damage, e.g. munitions
- Top event - the point at which control is lost over the hazard; e.g. munitions initiation
- Consequence - the outcome(s) of the top event

The tailored use of bow-tie diagrams in the SS Richard Montgomery work presented the munition initiation and consequence sequences for each scenario under consideration, including communication between holds (Figure 4, see over page), and informed the subsequent development of event and fault trees.

Fault trees and events

Fault trees were developed in order to address the question of the probability of mass detonation for the different scenarios explored in the bow-tie diagrams, including 'do nothing'. The basis of each tree was a set of discrete 'events', each of which had their own associated probabilities of occurring. This included potential incidents such as a ship colliding with the wreck, or shock to detonation transition (SDT) from one munition to another, for

Figure 3. Bow-tie diagram notation.



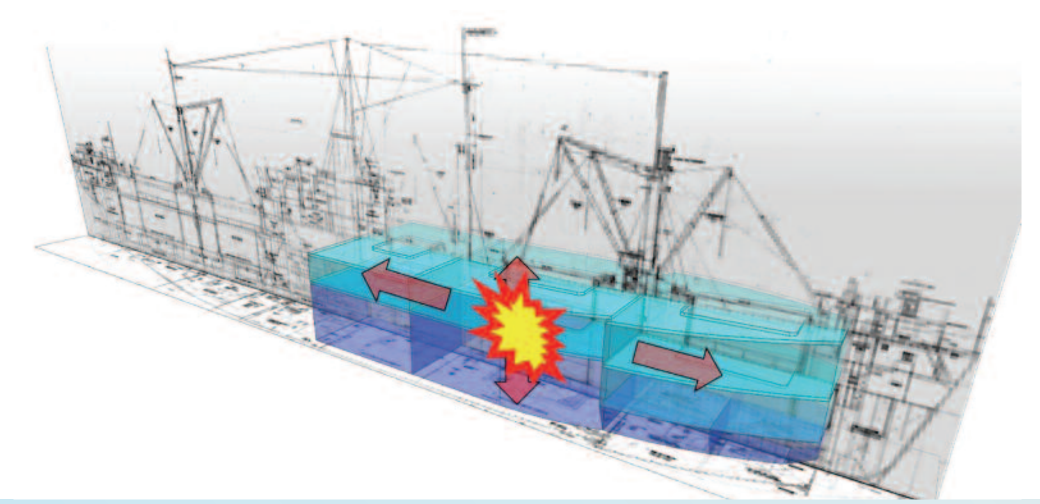


Figure 4. SS Richard Montgomery detonation communication.

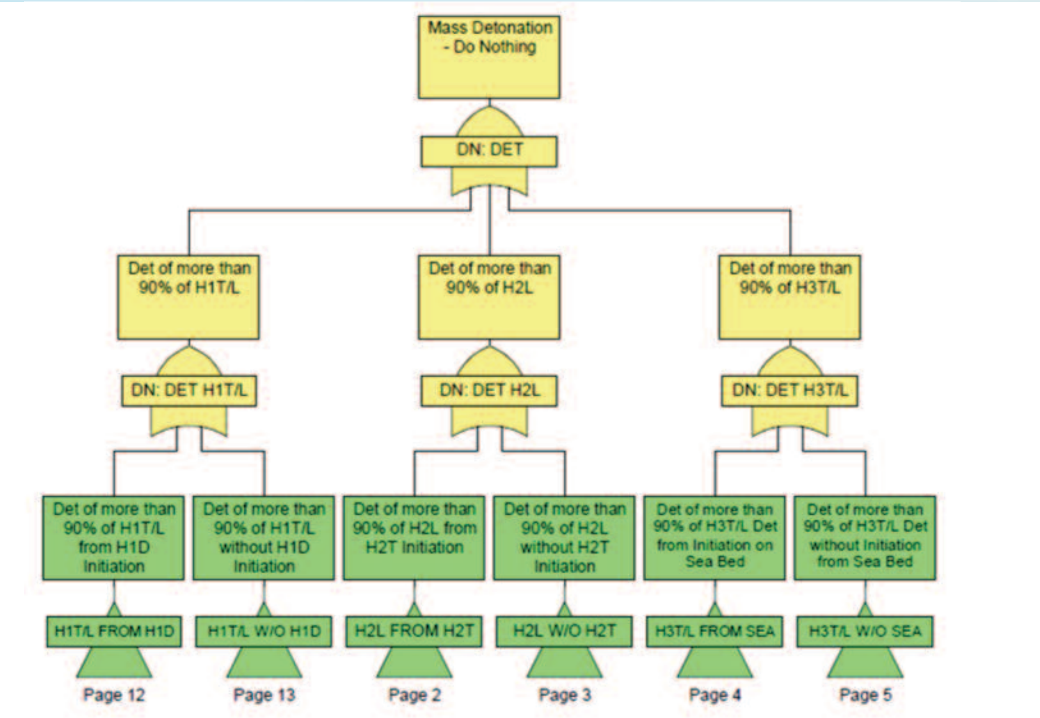


Figure 5. SS Richard Montgomery example fault tree.

example. Through the use of Boolean logic gates using AND or OR terms, the event probabilities could be combined to determine the 'top event' of mass detonation for any given scenario. Figure 5 shows a simplified example of a fault tree.

Given the nature of the events to be assessed (e.g. munitions in an unknown state within a deteriorating wreck), it was expected that there would be uncertainty associated with each probability assessment, and ultimately uncertainty associated with the calculated probability of mass detonation. Consequently it was recognised that the confidence limits associated with the calculated probability of mass detonation would need to be defined.

Confidence limits would be achieved through the use of Monte Carlo simulation methods to determine a probability density function (PDF). A PDF defines the relative likelihood for a variable to take on a given value. For example, the confidence limits of a probability of a munition deflagrating to detonation (DDT) could be represented as such[i]:

i. Please note - this example is illustrative only and does not represent actual pdf data.

- 10% likelihood that the probability is 1
- 50% likelihood that the probability is between 1 and 0.1
- 30% likelihood that the probability is between 0.1 and 0.01
- 10% likelihood that the probability is between 0.01 and 0.001

Tasks to quantify event probabilities

However, despite attempts to quantify the event probabilities themselves there was insufficient information to do so with any reasonable degree of accuracy. While some specific probabilities could reasonably be estimated as 1 (worst case), for many of the 170 individual events described by the bow-tie diagrams and fault trees, no probability assessment could be made.

The MWG determined that additional work would be required to quantify each event probability, by undertaking focussed tasks that constituted real-world study or investigation of each subject area. One hundred and twelve tasks were defined that would lead to, directly or indirectly, the ability to quantify each of the event probabilities. The tasks were broadly grouped into the following areas, and included live testing of replica and recovered munitions from the SS Richard Montgomery which would provide validation data for the modelling work:

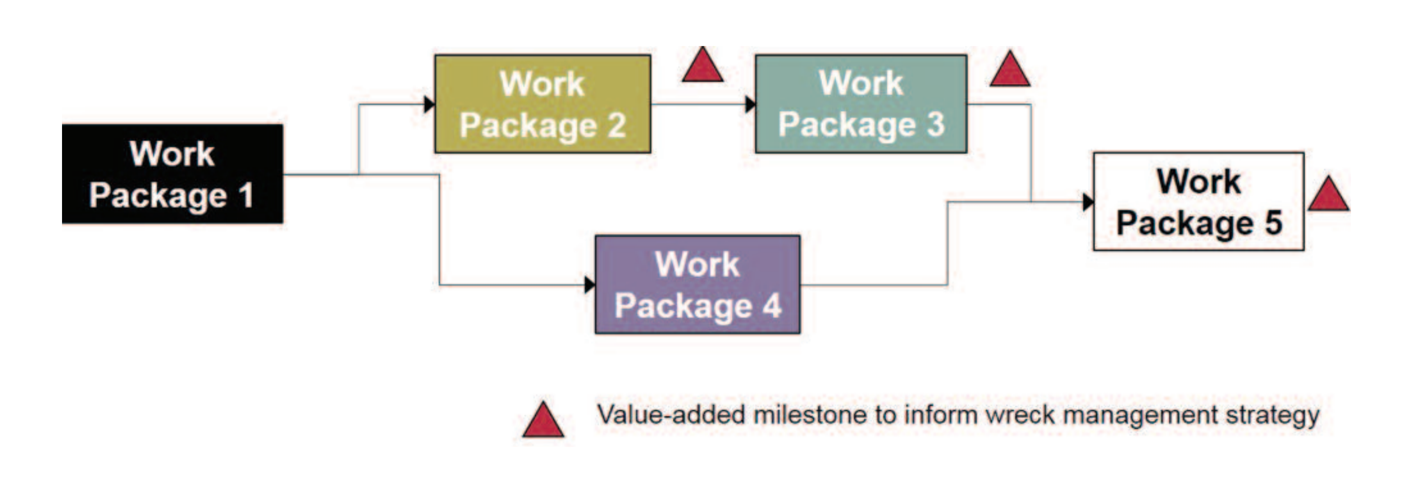


Figure 6. Representative network diagram for SS Richard Montgomery cost-effectiveness analysis.

- Threats
- Corrosion and collapse modelling
- Survey and spatial modelling
- Propagation/communication
- DDT/SDT
- Fuzes
- Pyrotechnics

Given the broad range of the work required to quantify the event probabilities, a cost-effectiveness study was required to determine how to achieve the optimum combination of tasks for a given budget, while keeping the probability confidence limits as tight as possible.

Task cost-effectiveness

Through analysis of the dependencies between tasks, it was found that there was a logical structure to the progression of work that would eventually provide all of the information required to calculate the probability of mass detonation. The tasks could not be evaluated in isolation and ranked by some measure of effectiveness alone, and then selected in or out of the next phase of work, but had to be seen in the context of the overall wreck as a complex system.

With the dependencies identified, natural break points in the network of tasks were identified that allowed them to be organised into discrete work packages (Figure 6 shows a general representation of the network).

If completed, each work package would provide the best possible information on a particular aspect of the problem, whether it was hull corrosion, SDT, or the likelihood of floating debris impacting the wreck with sufficient force to trigger a reaction from the munitions. By estimating the time and rough order of magnitude cost for each work package, a programme was developed for three different budgets, highlighting what could be achieved and what risks were likely to be carried if funding dropped below a certain threshold. This approach had the additional benefit of identifying milestones at which point the information collected could be used to directly inform and improve the DfT's wreck management strategy, as well as contribute to the probability of mass detonation calculation. For example, by determining the probability of the hull collapsing, it would also be possible to estimate the point in the future that this event would take place, after which the wreck's condition would start to change more significantly than it has done so far, with new potential consequences.

Summary

Through the use of innovation and collaboration between public, private and academic subject matter experts, the MWG developed a method to determine the probability of mass detonation of the munitions on board the SS Richard Montgomery. By using a systems approach to engineering, they assessed the most effective way to conduct the work, and added additional value by identifying areas of direct relevance to the wreck management strategy.

The SS Richard Montgomery represents a unique and significant problem to which there are no easy answers, as its continued existence after 70 years attests, However, the longer the wreck remains in place, the more complex it may become to understand it as the state of the structure, and potentially the munitions, continues to deteriorate.

References

1. Howard M, 2012, 'SS Richard Montgomery Structural Assessment', DE&S Naval Design Partnering, 100/100.
2. Bourneuf Jr. G, 'Workhorse of the Fleet: A History of the Liberty Ships', American Bureau of Shipping, 2008.
3. SS Richard Montgomery Review of Munitions Sensitivity Phase 1,FNC 47616-42559R, March 2015
4. 'SS Richard Montgomery Survey and Hull Thickness Report 2013', Maritime and Coastguard Agency, 2015,https://www.gov.uk/government/publications/the-ss-richard-montgomery-information-and-survey-reports
5. 'SS Richard Montgomery: Survey Report 2014', Maritime and Coastguard Agency, 2013, https://www.gov.uk/government/publications/the-ss-richard-montgomery-information-and-survey-reports

David Wyse and Rob Leary are Senior Consultants at Frazer-Nash Consultancy Ltd

This paper was first presented at the IExpE Conference 13th April, Telford, UK

Further information: r.leary@fnc.co.uk, www.fnc.co.uk

FRAZER-NASH CONSULTANCY

From battlefield to laboratory: blast waves and experimental techniques

This is the first in a series of four papers from the Royal British Legion Centre for Blast Injury Studies at Imperial College London (CBIS). The increased use of improvised explosives devices (IEDs) in conflict have brought the study of blast injury into sharper focus. Some aspects of blast injury have been well documented; the use of explosives in enclosed environments such as the mining industry with 'blast lung' being the most well known condition. This article will outline the scope of the threat, briefly discuss the output from explosive devices and then present a survey of experimental techniques that can be used to reproduce the effects of blast and 'solid blast' in a laboratory in a controlled and focused manner.

By **Dr W G Proud** BSc (Hons) PhD FInstP MRSC CChem CPhys, **T-T N Nguyen** BSc MSc, **D Sory** MSc MEng, **B J Butler** BSc MSc and **Dr K A Brown** BA BS DIC PhD CChem FInstP

Introduction

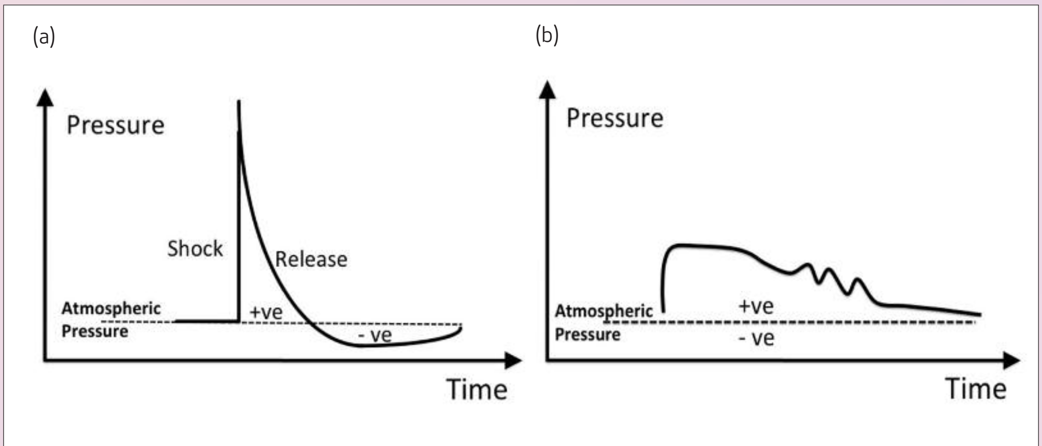
The effects of explosive loading on rocks, buildings and structures are well known to explosives engineers. In the military realm, studies of improving performance, delivery of explosive energy, and the counter-balance of developing suitable protection have been ongoing throughout recorded history. In recent conflicts a series of weapons have been fielded which use primarily blast effects[1,2]. The reason is that the combatants are using munitions in a relatively simplified arrangement to function anti-personnel or anti-vehicle land-mines. It is relatively easy to detect buried metal objects, so such devices may have low or no-metal content: many IEDs consist of a large explosive charge contained in a plastic vessel with a single detonator.

The detonation of weakly confined explosive means that blast is the dominant effect. The fragments and projectiles produced by such IEDs tend to be formed by the rocks and dirt surrounding the device, sometimes with the addition of sharp objects placed around the device.

In this respect, the effect of an IED is more akin to an accident in a quarry than that associated with a conventional military system..

Rapid evacuation of casualties and improved medical support have produced increased survival rates. The effect of this is that many who would have died in previous conflicts now survive but are more severly injured. The mitigation of the initial injury and the long-term rehabilitation of the survivors requires a deeper understanding of the injury process, the immediate trauma and the underlying changes in the human body that can lead to long-term medical conditions.

Figure1. (a) The classic Friedlander waveform seen in open-field detonation of bare explosive charges (b) Schematic of the waveform seen inside a vehicle.



Blast waves: Friedlander and complex

In many explosive textbooks the blast wave is presented in it simplest form, the Friedlander waveform[3]. This type of waveform, shown in Figure 1(a), corresponds to a detonation of a bare charge in an open field. The initial part of the blast consists of a sharp, discontinuous jump in pressure leading to a maximum loading pressure. This is followed by a slower decrease in pressure to a point lying below atmospheric pressure. This can be easily visualized; the initial expansion of the explosive products push outwards moving both themselves and the surrounding air away from the explosion site, thus leaving a lower pressure zone behind. As the blast energy dissipates, this lower pressure zone is then filled by gas sucked back towards the explosion. Measuring the precise shape of the pressure pulse produced by a bare charge is of use to engineers in terms of ranking the blast output of a particular energetic composition.

However, in a cluttered urban environment or in the confines of a vehicle, the presence of multiple reflective surfaces means a very complex waveform can be produced. Figure 1(b) shows a schematic of a blast wave that may be seen inside a vehicle. Instead of a high peak pressure, a much lower, longer-lasting pressure pulse is seen, with extra peaks and only a small, or absent region of sub-atmospheric pressure. In the vast majority of cases this wave will be more complex than shown in Figure 1(b).

Thermobaric weapons were developed in the late twentieth century and used an enhanced, long-lasting blast to push over buildings or demolish fortifications. However, most of the resulting damage and casualties seen when these systems were deployed were due to structural collapse of the building often masking the effect of injuries due to direct (or primary) blast injuries or violent acceleration.

Solid blast

With the introduction of all-metal battleships and high-velocity high-explosive munitions, the effects of blast and impact caused by the transmission of stress pulses through the solid structure of the vessel became more common. In the age of the Dreadnoughts it was common for experienced sailors to walk with bent knees, during battle, in order to mitigate the effect of violent jolts caused by this 'solid blast'. Such effects were more noticeable in the Second World War and resulted in a number of medical and scientific publications[4]. From the end of the Second World War onwards the relative decline in direct naval conflict compared to land and air operations meant that 'solid blast' was not a major subject of on-going study.

Recent studies within CBIS have focused on determining the forces involved in solid blast. In particular, the acceleration of 2 x 2.5 m steel plates, chosen to represent a simple model of the floor of a vehicle. The metal plate was fixed 50 cm above an explosive charge, the charge ranged from 1 kg to 3 kg and was buried with its upper side flush with the ground's surface. The velocity of the motion of the centre of the panel is shown in Figure 2. Also shown in the figure is acceleration of the plate only 5 cm away from the centre, this has a significantly lower velocity: while points 50 cm from the centre had peak velocities much less than 10 ms^{-1}. From this it can be seen that while the loading produces intense acceleration such effects are quite localized. This type of information is useful in the design of laboratory loading techniques for biological studies and also in the design of mitigation systems.

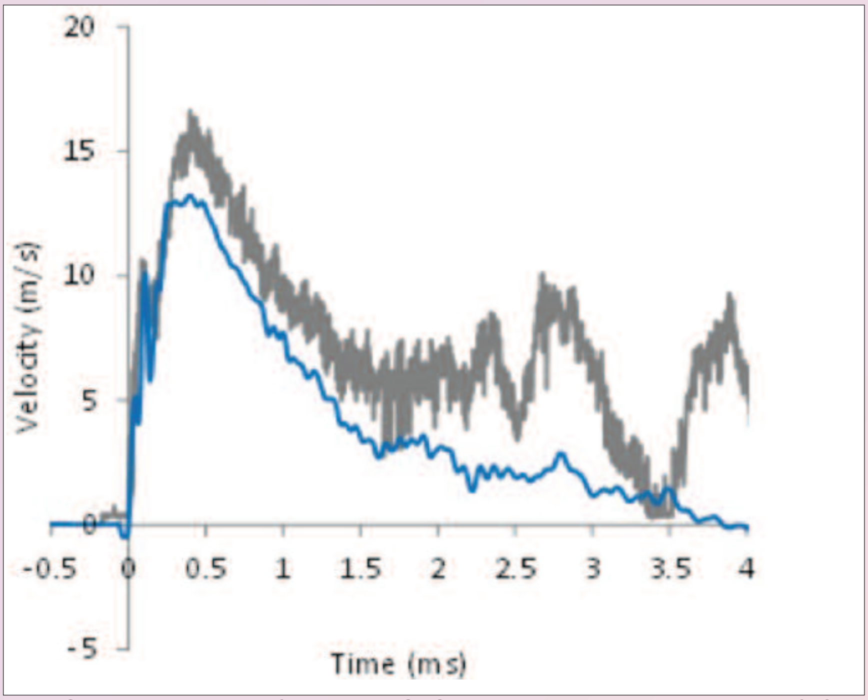


Figure 2. The velocity history of a steel plate 2 x 2.5 m in size, blast loaded at a distance of 50 cm by a kg explosive charge. The grey line indicate the velocity at the centre of the plate, the blue line at a point 5 cm from the centre, taken from[6].

Research strategy

It is obvious that the human body, and biological specimens in general, present a diverse system with many interdependent parts: much more complex than standard engineering materials. The blast loading wave, with the possibility of multiple wave reflections, partial mitigation or channeling by structures, presents a similarly complex system. It can be difficult to decide where to start: therefore, a multi-disciplinary approach was used to address the issues. As a point of principle the research focus of CBIS is guided by a number of factors; injuries seen in the combat environment; longer-term pathologies seen in recovering casualties; development of rehabilitation techniques and improved prosthetics. These areas will be the subject of other papers in this series. Figure 3 shows a simplified diagram of how these areas interact and the desired outcomes.

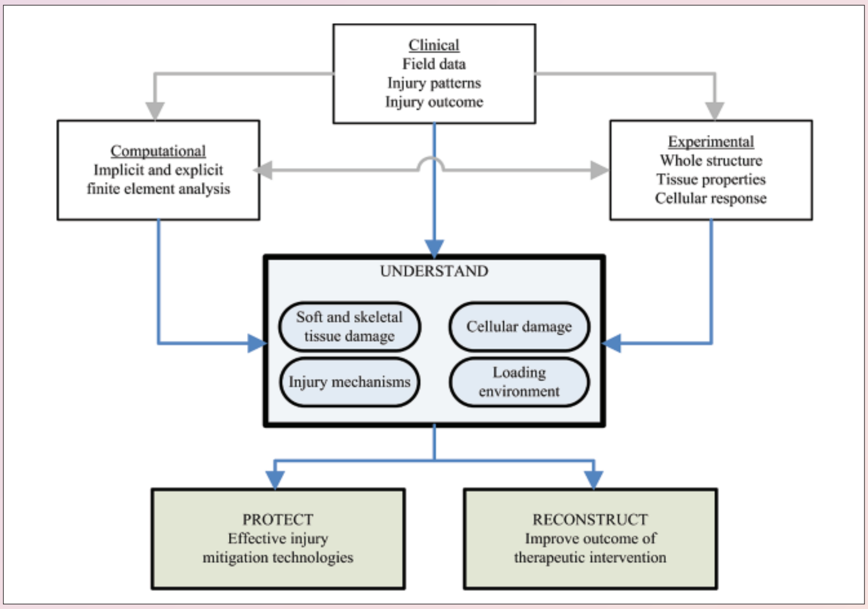


Figure 3. Overarching strategy of the CBIS.

Laboratory techniques

The study of the dynamic loading of materials is well established with a number of loading systems and accompanying high-speed diagnostics. These techniques allow materials to be loaded from quasi-static to high-intensity shock loading. A brief outline of a number of techniques follows: in each case some loading profiles and application to biological samples is presented. In many cases the loading platform has to be modified to allow the properties of the biological tissues to be measured. Biological materials can generally be classified as soft and heterogeneous, with a low sound speed and low strength. It is not surprising that many older studies focused on bone and muscle, which are similar in properties to a ceramic composite and polymer fibre, respectively. Historically, bone and muscle were often used in tools and hunting equipment before the corresponding modern engineering materials were developed.

Increased knowledge and inter-disciplinary interaction has meant that the need to keep biological materials fresh and chemically stable is now widely recognized. The result of careful handling mean these materials often show very reproducible mechanical behaviour but also improved handling allows post-loading recovery of the sample allowing in-depth biological characterization of any changes. Given that medical response may be caused by changes at a cellular level e.g. infection after trauma or on a much larger scale such as the amputation of a limb, the range of sample sizes is tremendous and requires careful thought on both the loading device and sample preparation.

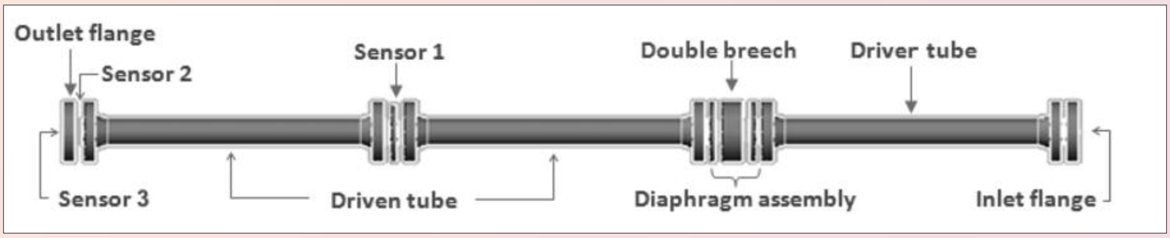


Figure 4. Schematic of the shock tube at the CBIS.

The Shock tube: blast waves without explosives

The shock tube is a versatile, simple device invented in 1899, able to generate a range of well-defined pressure pulses. The shock tube in CBIS is 3.8 m long, with an internal diameter of 59 mm (Figure 4). Compressed air is used to pressurize the driver section. This pressurized gas is held in position by a diaphragm. By bursting the aluminum or Mylar® diaphragms, blast waves with magnitudes between 0.5 to 17.0 bars are produced, equivalent to the output from a detonation of 20 kg TNT at distances of 1.2 to 12 m[7].

As the blast wave propagates along the shock tube, its evolution is monitored using piezoelectric transducers mounted into the sides of the tube. If the driving volume is changed the system can produce the classic Friedlander waveform or the longer output seen inside vehicles.

By a combination of the driving volume and choice of diaphragm the pressure pulse can be controlled in a relatively simple manner.

Perforated sheets and granular beds can be inserted into the driven section to reproduce blast attenuation effects. The magnitude of the pulse can be reduced by decreasing the area of the perforations (Figure 5A). Granular beds not only attenuate the blast but also transform the initial rise into a ramped structure, shown Figure 5B, where beds of different thicknesses are added to the end of the shock tube[7].

Loading techniques across the strain rates

While the shock tube can produce carefully controlled blast waves allowing the response of material to be studied, injury thresholds established, and global effects measured, the blast loading profile is still complex. The initial part of the wave is associated with intense but short-lived acceleration, the latter part with much lower but longer compression, the sub-atmospheric region with tensile forces. In all cases, many samples will also experience significant shear stress. In order to address this, a number of techniques are used to reproduce different elements of this profile. Figure 6 places these techniques in context, while the review by Field et al. gives more detail[7].

Low-rate loading

Soft tissues associated with skin and respiratory system are often damaged by blast[8]. Characterizing the material properties of these tissues over a range of loading rates representative of injury conditions is an important step towards developing biofidelic numerical models for mitigation and biomedical applications. Here we present the low-rate properties of fresh porcine skin harvested from different anatomical regions (rump, upper back and thigh). Cylindrical specimens, 8 mm in diameter, were obtained using a biopsy punch. These specimens were stored in phosphate buffered saline solution at 4°C until mechanical were tests performed, a maximum of 5 h post-mortem. Compression experiments were performed at different strain rates using an Instron 5566. Data obtained at a strain rate of 1.0 s^{-1} are shown in Figure 7. These data illustrate variation in the relative stiffness of these skin samples, reflecting differences in their underlying structure and compositions according to their anatomical origin.

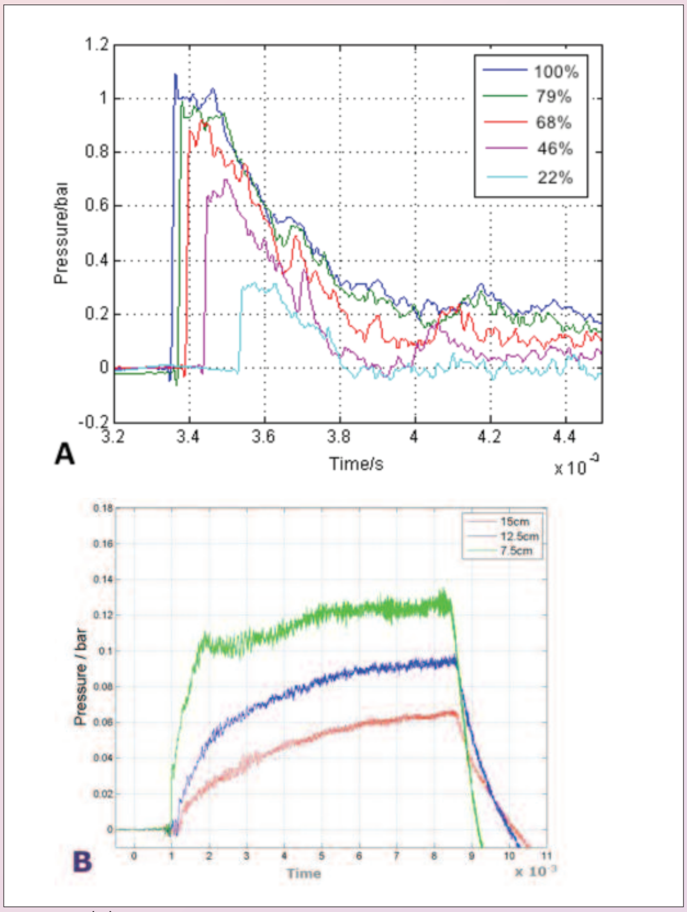
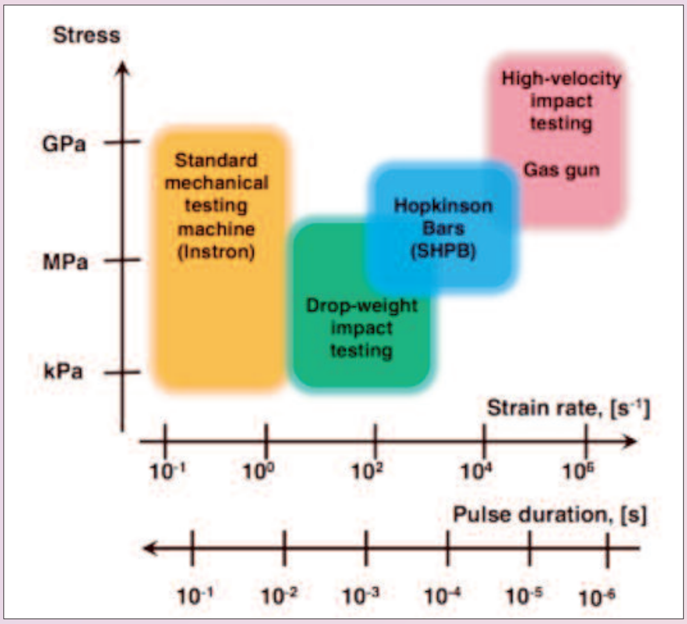


Figure 5: (A) Transmitted pressures for various open areas of perforated galvanized steel sheet and (B) Pressures profiles showing effects of granular beds of 2mm diameter glass spheres 7.5, 12.5 and 15 cm thick. Taken from[6].

Figure 6. Pressure-time outputs from the loading devices described in this article.



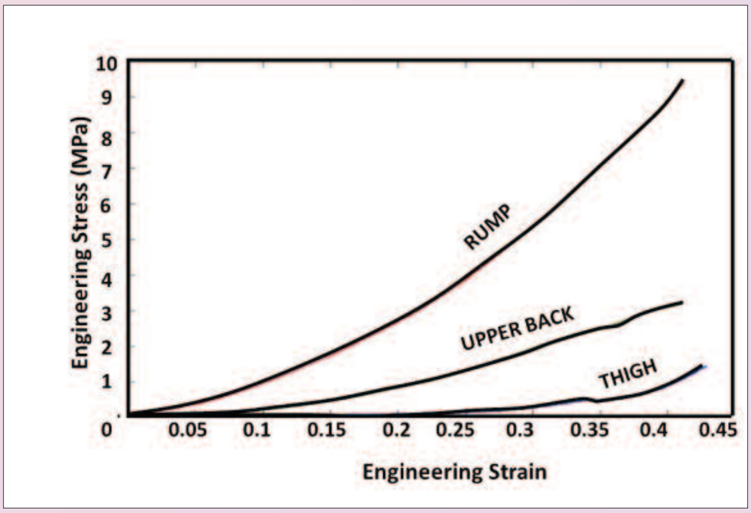


Figure 7. Comparison of the engineering stress-strain curves for skin taken from different anatomical regions. These were obtained on an Instron testing rig at a strain rate of 1 s^{-1}. Taken from[9].

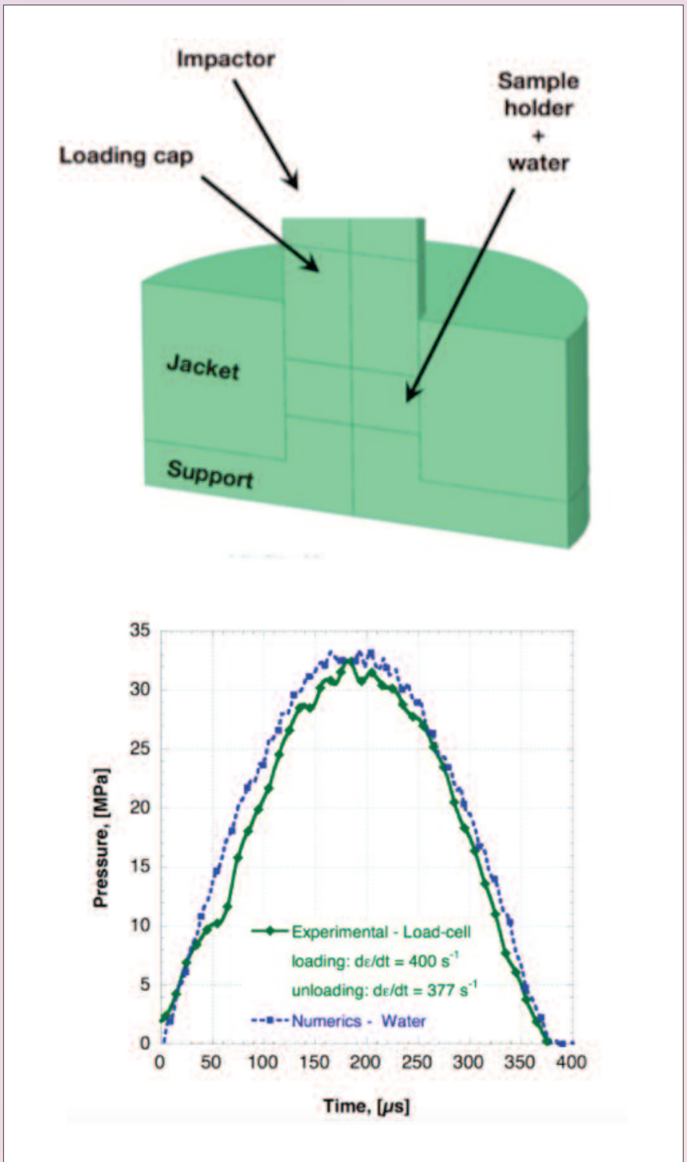


Figure 8. Top: The sample holder arrangement. Below: the output from the small drop-weight system used in CBIS. The green line is the output from the system; the blue line shows modeling of the output based on knowledge of the sample properties.

After compression, skin tissue samples were recovered and fixed in formaldehyde for 24 h and sections stained with Masson's trichrome to investigate the damage caused: the increased presence of dye indicates disruption of tissue organization, most likely due to damage of collagen structures in the skin. When these histology results are compared to those from samples, which have been dynamically loaded in a Hopkinson bar it can be seen that the level of dye infiltration decreases as the applied strain rate of loading increases indicating localized, severe damage.

Drop-weight

The drop-weight, sometimes called a fall-hammer, uses a weight falling under gravity to provide an impulse to a sample. In this regard it is a simple device to visualize. However, one of the complications of this device is that we are moving from a regime where the sample sees the load throughout the structure, to one where it is the wave transmission through the sample and the loading device, which produces the output. To have clear results from a drop-weight for these soft materials the effect of the impacting weight impacting the sample more than once, due to bouncing, has been eliminated due to a catching device mounted on the system. Similarly the reflections or ringing within the frame of the drop-weight has been reduced by careful attention to the loading frame.

The combination of these factors means the output shown in Figure 8 can be achieved.

In the example shown in Figure 8 the experimental data is shown along with the output of numerical modeling of the response of the system and sample. The agreement is close showing how such a system can be used to compare the predicted response of the material with experimentally derived values: in this case using water as a basis for the model when studying cells in a liquid growth media. This comparison of expected outcome with experimental results is key to developing appropriate constitutive models for biological materials under blast and impact loading.

Split Hopkinson Pressure Bar

The Split Hopkinson Pressure Bar (SHPB) is a system where the impact of a striker on a cylindrical rod produces stress pulses, which are transmitted onto a sample. The stress pulse is partially transmitted through, and partially reflected from, the sample: the shape and intensity of the waves is captured using strain gauges mounted on the rods. The simplest arrangement for the Hopkinson Bar is shown in Figure 9 (See over page). The SHPB system used in these experiments included a momentum capture system so the sample only saw one stress pulse and the choice of rod materials was made to be close in mechanical impedance with the sample material.

These studies have initially focused on understanding more about the resilience and functional properties of cells that play significant roles in blast injury. In particular the survivability of mesenchymal stem cells (MSCs), a cell-type identified to be of potential importance in the development of heterotopic ossification, a post-traumatic condition involving the formation of ectopic bone following blast injury[10,11].

Using a SHPB system[12], fitted a biocompatible confinement chamber Figure 9, cells in solution or adhered monolayers to coverslips were subjected to a range of pressure pulses. The range of pressure pulses and durations could be varied from 100 to 500 atm and from 100 to 200μs.

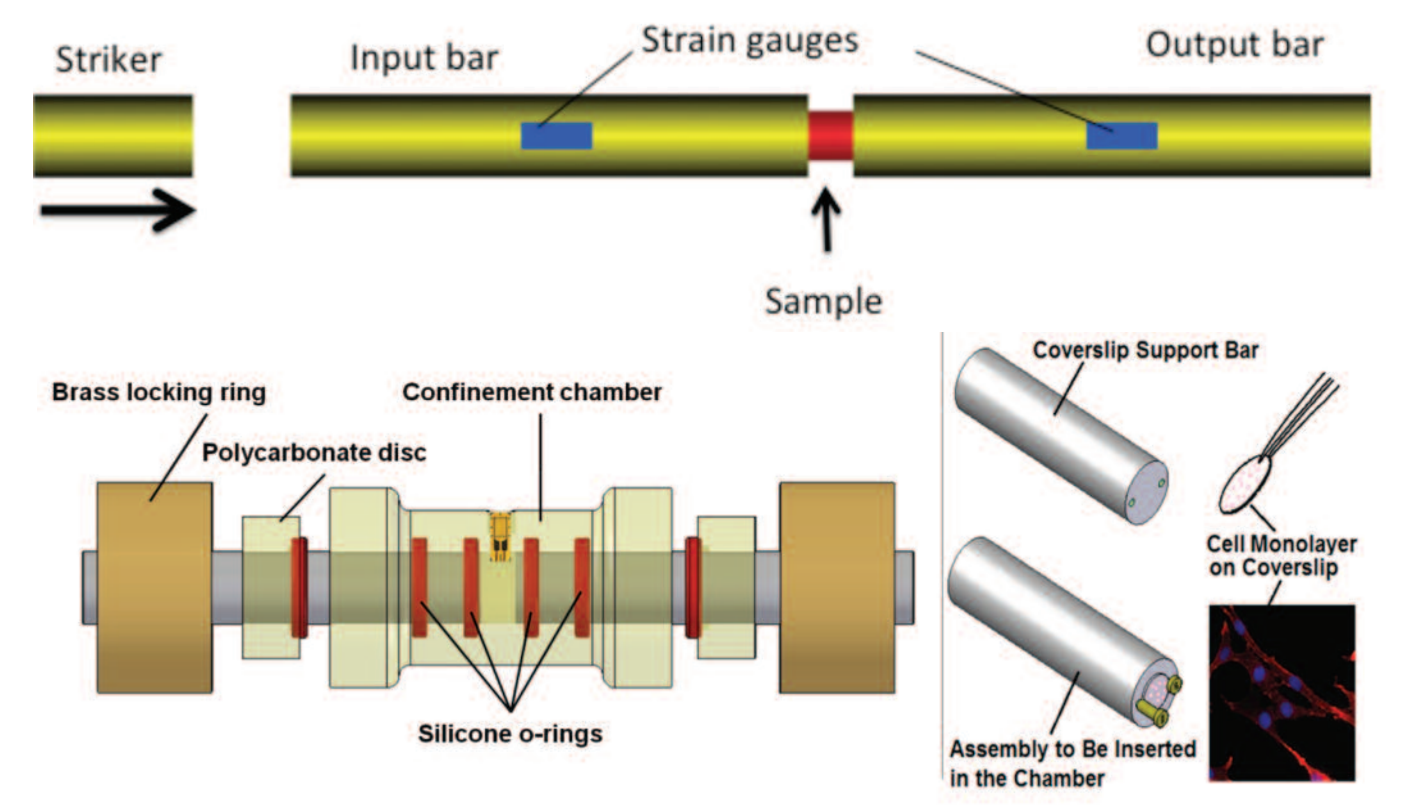


Figure 9. Top: Schematic of Split Hopkinson Pressure Bar arrangement.
Bottom: Experimental assembly for confined SHPB experiments with cells in solution or as monolayers on coverslips.

The chamber is composed of a polycarbonate cylinder with inner O-ring grooves. The chamber is mounted on a compressive SHPB system composed of four bars made from Inconel steel, 12.7 mm in diameter, and 190 mm (striker) or 500 mm (input, output and momentum trap) in length. Liquid samples are inserted using a syringe through 1 mm diameter counter-bored holes, The chamber is instrumented with two strain gauges GFLA-3-350-70 (Techni Measure, UK) located halfway along the chamber length and diametrically opposite each other in order to measure the circumferential strain in order to fully characterize the samples loading state during compression.

The survival of MSCs post compression was assessed using both Trypan blue dye to count cells and by measuring the cell respiration levels using the MTS assay. Results give quantitative values showing cell survival decreases as a function of the intensity of the pressure pulse Figure 10. The exact nature of the correlation between the peak pressure and impulse on cell viability is complicated both in this experiment and in full blast loading by other mechanical phenomena such as cavitation which has previously reported in extracorporeal shock wave treatment and laser shock experiments[13,14]. These parameters are undergoing further study, however, a body of evidence that damaged MSCs can promote bone formation is emerging[10].

The stress pulse height and duration delivered by the SHPB to the sample can be varied systematically by changing the material, length and velocity of the impactor bar. More subtle changes to the loading pulse can be achieved by changing the properties of the interface between the impactor and the input rod: 'pulse-shaping'. Examples of the some of range of pulse shapes, which can be produced, are shown in Figure 11.

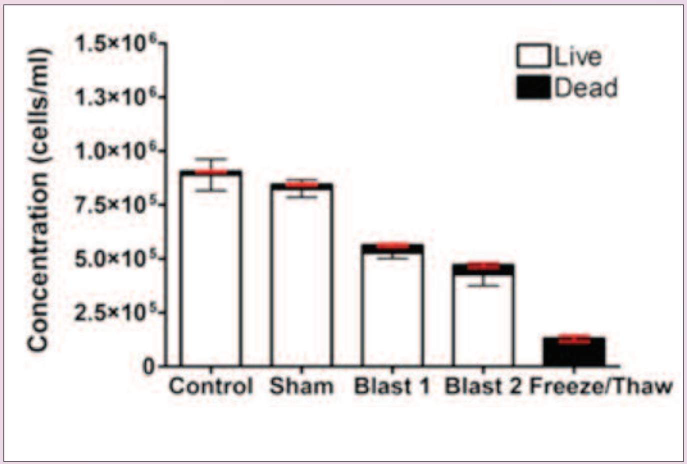


Figure 10. Comparisons of MSC survival at dynamic pressures, samples exposed to a 'blast' in the SHPB compared to control, sham and freeze thaw. (Note: Control samples are those materials which are not subject to any manipulation, while 'sham' samples experience the same mechanical manipulations, are placed in and recovered from the SHPB but are not pressure loaded by the SHPB).

Extreme pressures: plate impact

Intense shock wave loading, associated with detonation pressures can be obtained using plate impact; a technique in which a flat disc of sample material is struck by a fast moving accurately aligned impacting plate. The pressures obtained using this technique can be of the order of 50 GPa, well above the detonation pressure of many commercial explosives[7]. While a number of studies exist of biological materials showing the mechanical response, it is highly unlikely that a human exposed to such a violently dynamic mechanical load would survive. However, such studies are of interest to the survival of small life forms (e.g. bacteria) in comet and asteroid impact.

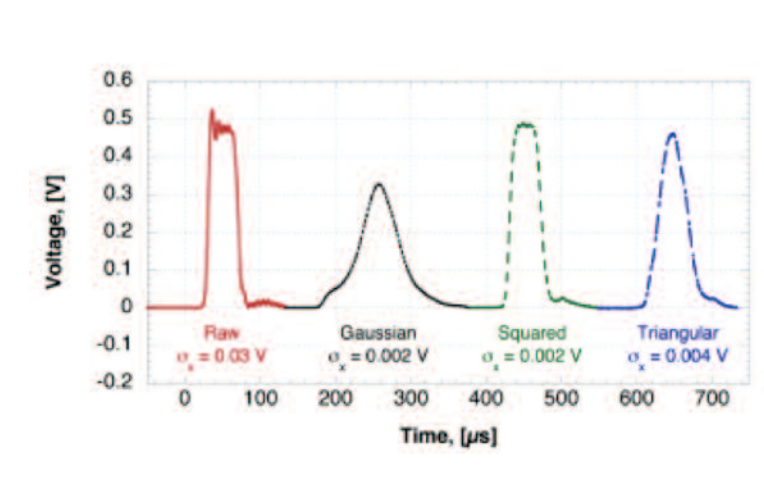


Figure 11: Examples of pulse-shapes produced by a SHPB system produced by changing the striker-input bar interface.

Ballistic impact

Though current conflict has seen increased casualties due to blast waves, 'direct' or 'solid'. There are numerous studies of ballistic impact by bullets, fragment-simulating projectiles (FSPs), or other projectiles. While space does not permit an adequate discussion in this article, it is important to recognize that the loading techniques here can be used to develop numerical constitutive relations for biological tissues which can then be used to predict the penetration and damage inflicted by projectile impact.

Conclusion

This article has briefly outlined some of the loading techniques used in the study of biological materials to determine the response of biomaterials and to reproduce the loading produced by large explosive charges in the laboratory. A summary is presented in Table 1. It is clear that a full understanding of human injury under the complexity of blast loading requires close working between explosive engineers, physicists, bioengineers, bioscientists and the medical community. Such a formation exists at the CBIS where military medical officers work side by side with scientists and engineers. Similarly the development of practical blast mitigation protection depends on determining the injury/damage thresholds and the defining the underlying effect of variables such as stress level, loading rate and duration.

Platform	Strain rate (s^{-1})	Pulse duration (s)	Impulse (MPa.s)
(Quasi-static) Instron	0.002 - 0.1	0.1 - 1	5 - 2000
Dropweight	150 - 1000	0.0002 -0.001	0.05
Split Hopkinson Pressure Bar	1000 - 6000	0.0003	0.005

Table 1. Summary of loading parameters of the principal devices described in this article.

References

1. Owens, B. D., Kragh Jr, J. F., Macaitis, J., Svoboda, S. J. &Wenke, J. C. 2007 Characterization of extremity wounds inOperation Iraqi Freedom and Operation Enduring Freedom. J. Orthop. Trauma 21, 254–257.
2. Ramasamy, A., Harrisson, S., Lasrado, I. & Stewart, M. P. 2009 A review of casualties during the Iraqi insurgency 2006—a British field hospital experience. Injury 40, 493–497.
3. G. Kinney, and K. Graham. 1985, Explosive shock in air. Springer-Verlag, Berlin.
4. Draeger RH, Barr JS. Blast injury. JAMA 1946:762–7.
5. Newell N., Neal W., Pandelani T., Reinecke D., Proud W.G. and Masouros S.D., The Dynamic Behaviour of the Floor of a Surrogate Vehicle Under Explosive Blast Loading, Journal of Materials Science Research; Vol. 5, No. 2; 2016, 59-67
6. T-T. Nguyen, T. Davey, and W. Proud. 2014 Percolation of gas and attenuation of shock waves through granular beds and perforated sheets, in proc. New Trends in Research of Energetic Materials, Pardubice, Czech Republic.
7. J.E. Field, S.M. Walley, W.G. Proud, H.T. Goldrein, C.R. Siviour, Review of experimental techniques for high rate deformation and shock studies, IJIE, 30 (2004) 725–775
8. Christopherson GT, and Nesti LJ, Stem Cell Research & Therapy 2011, 2:40
9. W.G. Proud, T.-T.N. Nguyen, C. Bo, B.J. Butler, R.L. Boddy, A. Williams, S. Masouros, and K.A. Brown, The High-Strain Rate Loading of Structural Biological Materials, Metallurigical and Materials Trans. A Vol. 46A, Oct 2015, 4559- 4566
10. Cipriano CA, Pill SG, Keenan MA, 2009, Heterotopic ossification followingtraumatic brain injury and spinal cord injury. J Am Acad Orthop Surg 2009, 17:689-697.
11. ackson WM, Aragon AB, Bulken-Hoover JD, Nesti LJ, Tuan RS, 2009, Putative heterotopic ossification progenitor cells derived from traumatized muscle. J Orthop Res 2009, 27:1645-1651.
12. Bo, C., Balzer, J., Brown, K. A., Walley, S. M., & Proud, W. G. 2011 Development of a chamber to investigate high-intensity compression waves upon live cell cultures Eur Phys J Appl Phys 55, 1-5.
13. Delius, M 1994 Shock Waves 4 55-72
14. Kodama, T, Hamblin M R and Doukas, A G 2000 Biophys. J. 79 1107-1122

Acknowledgements

The authors wish to acknowledge the Royal British Legion and Imperial College London for the support of this research. The Institute of Shock Physics acknowledges the support of the Atomic Weapons Establishment, Aldermaston.

Acknowledgments for specific research areas can be found in the source papers for this article; however, the authors wish to express their gratitude for the Mechanical workshops in Imperial College London and the Cavendish Laboratory in the construction of the devices described in this article.

Dr WG Proud, Reader in Shock Physics, T-T N Nguyen and D Sory, PhD students, are based at the Institute of Shock Physics, Imperial College London.

Dr. K.A. Brown, Senior Research Fellow and B.J. Butler, PhD student, are at the Cavendish Laboratory, University of Cambridge.

All authors are in receipt of funding from the Royal British Legion

Further information: w.proud@imperial.ac.uk

Using the Explosive Substances and Articles National Occupational Standards – what results?

By **Denise Clarke** BA MA MIoD AIExpE

In the previous article of this series (*Explosives Engineering* March 2016) we looked at the practical applications of the Explosive Substances and Articles (ESA) National Occupational Standards (NOS). In this article, we consider some of the changes resulting from the implementation of the NOS.

Proof of Competence

There are numerous reasons that organizations implement NOS – it might be to provide a framework for a systematic and objective process that provides for the recruitment, training, development and management of explosives workers within an organization or industry so that future business needs can be met by a technically skilled workforce. It might be because people are expected to demonstrate competence (as does the UK's Ministry of Defence (MoD)) of its explosives workers; it might be because the company may be able to negotiate reductions in its insurance premiums if it can prove the competence of its staff (which can be done through the achievement of a qualified workforce); it might be because an organization wants to standardize its systems, processes and quality standards or it might be because a customer plans to audit its suppliers and the consistent quality of work may be enhanced by implementing working to standards.

The UK's Health and Safety Executive has also stated that if it carries out an investigation following an explosives incident, one of its first priorities will be to assess the competence of the people working a process as measured against the ESA NOS. All very diverse reasons for implementing standards and no doubt, there are many other reasons too.

Operational Improvements

For many, the benefits lie in the development of people and we often hear of the growth in confidence that comes with greater understanding of what is expected. People's ability to meet increasing challenges which comes from increased confidence in turn can lead to people seeking out more responsibility, developmental opportunities and seeking for themselves new and more challenging career goals. However, many of the benefits of working to standards are reflected in the bottom line. In 1996, I visited Hydro Polymers, a chemical company based in the north east of England to find out about their experiences in implementing National Vocational Qualifications (NVQs) that were based on NOS (these were largely in Process Operations and Engineering Maintenance), Investors in People and other initiatives focused on enhancing the skills of its workforce. The story remains relevant to today:

… A combination of very out of date equipment, rigid job demarcation, too many links in the production chain and laboriously slow processes had all conspired to threaten the future of the company,

Over an eight year period, the company was restructured into teams, the terms and conditions were reviewed, and the company embarked on a massive culture change. Employee numbers dropped from 700 to a current level of 500. But by introducing a number of initiatives – including Investors in People and NVQs – to achieve all staff's active participation in improving business efficiency, Hydro Polymers has found enormous business benefits.

- Savings of £7 million have been made in 5 years
- Productivity has risen site-wide (i.e. including non-production staff) from 174 tons per person employed to 450 tons per person
- A suggestion from a Process Operator has resulted in improving efficiency by charging agents simultaneously (instead of consecutively): this has reduced the charging time from one hour to 25 minutes, and the whole reaction cycle has reduced by 25%
- These reductions have meant that production has increased from 10 tons of resin per hour to 16 tons per hour
- Suggestions from staff put forward under the TQ Reward and Recognition scheme have resulted in savings in one project alone of £250K.

For one company, numerous changes have resulted from using the ESA NOS even though their implementation is still in its infancy. First, the implementation of the ESA NOS on such a grand scale (around 600 explosives workers across three UK sites) necessitated the appointment of a manager which was incorporated into the specific role of Explosives Training. Second, the terms of reference for all explosives workers were aligned directly to the ESA NOS for explosives storage operators, supervisors and managers.

Driven by the need to comply with MoD and HSE regulations, the implementation of the ESA NOS has influenced how the ranges look at the competence of range staff and, as a result, 13 Trials Conducting Officers and related staff are currently working toward a L4 Diploma in Defence Range Safety. The company is therefore now able to show that its senior range staff can demonstrate their competence as required by the MoD's published requirements (see the article in *Explosives Engineering* March 2016).

The company's implementation of the ESA NOS has identified the need for more training and development and existing training has been rewritten to accommodate ESA NOS terminology. Consequently, it is easier to identify training gaps – for example, a need has been identified for more training on explosives awareness that will meet the requirements of the ESA NOS.

The company runs a scheme that is designed to encourage people to identify and rectify things that might improve workplace efficiency and safety and report them, in so doing, share best practice. It is noticeable that the quality of items reported has improved of late. As a result of the investment made by the company in its staff, people feel valued which in turn has boosted their self confidence and workers now feel more confident about making suggestions for improvement. The company also runs a staff suggestion scheme that is a business-wide scheme and to which all employees can contribute. This scheme provides a useful vehicle for the suggestions identified through the implementation of the ESA NOS. For example, people's suggestions on long established processes have resulted in their becoming more safe and efficient.

Work structures are already tightly specified but now the company has the assurance and proof that its processes are operated correctly. However, as the Hazardous Area Work Instructions come up for review, they are being reviewed with the ESA NOS in mind and adapted where necessary to meet the standards.

Safety Performance Indicators (SPIs) show that, historically, of the safety control measures that have failed, one of the top four points to competence issues. Now, it is easier to target the failures and understand the reasons for them, in turn, making it easier to address them. There are now fewer competence- related failures as a result of implementing the ESA NOS because it is easier to take preventive action. When managers investigate instances where a process went wrong, it is now done with the ESA NOS in mind: as they are written as specifications of the outcomes of best practice, this can therefore lead managers to making recommendations of better ways of working.

A further use of the ESA NOS has been to complement the achievement of other accreditation standards, such as the ISO xx001 series.

The Human Dimension

For the MoD, the ESA NOS have been used for altogether different purposes. Historically, the competence of explosives workers was often assumed and was retained within a small and shrinking community; it is now defined, is openly available and therefore offers opportunities for wide engagement and growth.

The ESA NOS have provided the catalyst to 'brigade' employers within a small sector to work collaboratively in sustaining explosives skills capability. The NOS focus on outcomes which employers generally recognize, which offer a common language or a bridge by which they can link their diverse businesses objectives to common issues and collaborative opportunities. Evidence of this is the continued work of the Standard Setting Body for Explosives, Munitions and Search Occupations (SSB for EMSO), the creation of the Sector Skills Strategy Group (SSSG) and the Development Office for Explosives Skills (DOES).

A collaborative approach to sustaining the UK's explosives skills provides the sector with resilience and cost-effective skill development solutions i.e.:

- resilience: it offers a national strategy and is therefore relatively immune to individual organizational changes while offering vocational and professional careers across the industry to help attract and retain talent;
- cost-effective: this is achieved through joint training, education and worker exchange opportunities.

A common theme amongst those interviewed for this article is that the use of the ESA NOS has also raised awareness across a wide employee base of the need for people to demonstrate their explosives competence and the need to recognize and reward achievements. For many, the post assessment feedback process has helped users to gain clearer understanding of what is expected of them and the expected quality standards. By making clearer what happens next and the consequences of their actions, it has also "woken them up to the processes and protocols they must follow" and helped them to gain a team focus so that they understand their own contribution to the team and the achievement of its goals. One manager said that working to the ESA NOS had "given the workers a pride in what they do because the ESA NOS recognizes their contribution". Conversely, managers are more aware of how work is structured and what might be improved - for example, the overlaps and distinctions between Ammunition Workers and Explosives Inspectors. As a result of

mapping these roles to the ESA NOS, the standards are now being used to cross-train both groups which will ultimately result in a more flexible workforce.

One company has produced terms of reference (ToR) for all its explosives workers which are linked to the ESA NOS as well as a "Competence certificate". These documents set out what is required of each worker (as described by the ESA NOS) and provides a scale for the extent to which they have achieved the requirements. The scoring system is as follows:
1 (works under supervision)
2 (works unsupervised) and
3 (supervises others).
An extract of the ToRs is shown below.

Terms of Reference (ToRs) for a Range Worker

Role holder is accountable to the Manager
Assist with preparation of batteries and equipment for trials, disposals and proof
Assist with the firing of trials, disposals and proof as required
Assist with post-preparation of batteries and equipment following activities, including cleaning and returning of stores
Carry out area/stop-gate sentry duties when required
Assist the Foreman with road closures when required
Ensure you comply with instructions within Risk Assessments, Task Instructions and Trials paperwork
Carry out duties in a safe and compliant manner Etc. etc.

Another company has found ESA NOS to be useful when auditing the competence of staff across the various business areas and to standardize the level of assessment. Conversely, it has also been useful to team members undergoing training to be aware of the standards that define and underpin competence in order to give transparency across the business. The use of the standards has also given a common goal to the staff who work with explosives although sometimes they do so in isolation. Using the common language of the NOS has allowed staff to communicate easily and simply in an otherwise technical environment. Or, to put it simply, "using the common standard of the ESA NOS allows us to look for training and development opportunities without getting too tangled up in the how, what and why".

This company has also found that the ESA NOS have been found to be particularly helpful in assessing the competence of staff under training, in particular, in assessing the competence of the role holder of Explosives Practitioner – Team Member. A manager assessing someone observed that a process did not go as well as had been expected. Working with the ESA NOS relevant to that process enabled him to explain simply where the team member had done well and exactly where he had not done so well. This enabled future development needs to be pinpointed. However, it also meant that the individual knew what it was that he did not know and the manager was absolutely clear about the capabilities and areas for development of his staff.

The use of ESA NOS in the UK is progressing slowly but their uptake is improving as more companies see the benefits that the ESA NOS provide for their workforce and the business. Whilst the UK Regulator expresses interest in explosives competence, the main drive is from within the explosives community.

Note to readers: the ESA standards are available free of charge and can be downloaded from:
www.homelandsecurityqualifications.co.uk/documents

This article first appeared in the SAFEX Newsletter No.47, 4th Qtr. 2013 and has been reproduced here with the kind permission of the publisher.

Denise Clarke in Managing Director of Homelands Security Qualifications (HSQ) - a British-based awarding body that specializes in the award of explosives-related qualifications.

Further information:
denise.clarke@homelandsecurityqualifications.co.uk

The Bennett file

Our columnist John Bennett tells us of his family tradition

In Elaine Moore's column in the spring edition of *Fireworks*, she examined what made ordinary people into firework enthusiasts. 'Imagine [she began] a group of children. Child A grows up with the tradition of family fireworks in the back garden; Child B is lucky enough to have parents who can afford large firework displays every November; Child C has an elder sister whose boyfriend brings fireworks to impress the younger sibling; Child D doesn't like fireworks; Child E is frightened of the bangs the fireworks make; Child X is forbidden from seeing any fireworks and the most he can hope for is a sneaky peak through the curtains where he might be lucky enough to glimpse the neighbour's display.'

Since I fall so comfortably into the 'Child A' group, it has long fascinated me to know what made others into firework enthusiasts – when they did not benefit from the steady, reliable, sensible background of a firework loving family. It was Wilf Scott, surely one of the world's most famous pyrotechnicians, who began this thought process by telling me that he hated fireworks when he was young. I can also recall those who have told me that 'they drifted into an enthusiasm for fireworks'.

It is certainly not my intention to duplicate what Elaine has written – it is unlikely that anyone could explain the situation as well as she has done – but to concentrate on Child A because this group so aptly fits my own situation.

When I think back to the preparations in my garden in Barkingside, it was just part of life. Yes, the trellis that originally fenced off the first flower bed but was brought into more productive use in acting as an ideal frame for the multitude of different Catherine wheels was almost made to be hung over a post. Wasn't that what all families did? The metal table was only ever used on Guy Fawkes' Night – of course it was; it was the firework table. The galvanised buckets were employed as firework pales –filled with earth and placed either on or under the metal table, ready for fireworks to be inserted into them. I think it would have shocked me if they had been employed for gardening or carrying water – or any such alien use. All occupied a place in the 'garage' – we had no car and therefore this unlit and dingy building held such things.

When my Dad and I had returned from a firework buying expedition it was expected that we should lay out and examine our purchases. My mother would have found it strange had I not brought them out every day to fondle, list – and later photograph. Dad sought the sources of Brock's, Wells', Pain's and Standard – while I included Wessex, Wizard, Astra, Benwell (and, when we moved west, Rainbow). Yes, we differed slightly in that he insisted on quality whereas, to me, a firework was a firework and the prettier the label the more desirable the item.

A Wells' Shimmering Cascade (top) illuminates the table – the trellis is long gone.

And, of course, the extended family would gather – almost always at Barkingside but once at my uncle and aunt's house at Newbury Park. Now, there was another family locked into the family tradition – or at least I thought so at the time. Perhaps they were supporting me – as they did in other areas. But, as far as my uncle was concerned, encouragement from this ARP warden whose hand had a constant tremor from his First World War experiences in the navy, encouragement was taken to extremes. It was he who sourced the Wells' ARP Thunderflashes and the smoke bomb for our 'displays' – perhaps the latter was deemed the least acceptable aspect of the night – and was never experienced after its dramatic introduction.

My daughter grew up with fireworks and, now, my grandchildren treat fireworks as a normal part of everyday life. While my daughter is a display firer – or was until the family came along – and will, I understand, continue to tread the muddy fields lugging mortars when the children are grown sufficiently to assist. It's all very natural isn't it? Perhaps the most encouraging thing my eldest grandchild has said to me is – after a back garden firework 'party' – 'Grandpa, we must have more fireworks; Grandpa, I really, really need some more fireworks.' I can understand that need and will be doing better next year!

John Bennett is editor of Fireworks, a magazine for enthusiasts and the trade. It is obtainable, by credit card on the website www.fireworks-mag.org or, by post, from Fireworks, PO Box 40, Bexhill TN40 1GX (tel: 01424 733050; email: editor@fireworks-mag.org).

Defence Academy of the United Kingdom

Cranfield UNIVERSITY
Defence and Security

Ordnance Munitions and Explosives Symposium

1 – 2 November 2016

Event time: 10:00

Location:
Defence Academy of the United Kingdom, Shrivenham

Call for Abstracts

Cranfield University at the Defence Academy of the United Kingdom at Shrivenham is hosting the 2016 **Ordnance, Munitions and Explosives (OME) Symposium**, on behalf of the Sector Skills Strategy Group (SSSG) of the explosives industry.

We have pleasure in inviting you to contribute by presenting a topic to complement those provided by invited speakers. The theme of the symposium will be "Technology Risk in Acquisition". This will include the risks associated with the use of energetic materials in weapon systems. Topics of interest may include, but not exclusively:

- Emerging requirements of the three single services – the perspectives of the Front Line Commands.
- A Project Team perspective of the issues and challenges associated with the management of general munitions and complex weapon systems and their energetic materials.
- An international perspective on the challenges in bringing new munitions and energetic materials into service
- An industry perspective on practical solutions to problems associated with existing and new materials.
- A view from the research community on likely trends in the development of new energetic materials.

If you wish to submit an abstract on the topics listed above, or on a topic that you consider is also relevant to the overall theme, please email your abstract of around 200 words to caroline@symposiaatshrivenham.com by Friday 27th May 2016. Papers should be planned to take 20 minutes to present, followed by 10 minutes for questions

Acceptance of papers will be notified at the beginning of July and authors will be eligible for a reduction in Registration Fees.

For further information, sponsorship, display opportunities
and online registration
please visit www.symposiaatshrivenham.com

Institute of Explosives Engineers
VOICE OF THE EXPLOSIVES INDUSTRIES

Ministry of Defence
de&s

Second World War torpedo detonated

A seven-metre torpedo believed to have been fired at HMS Royal Oak by a German submarine in 1939 was safely detonated on 6th April 2016. Royal Navy divers attached explosives to the torpedo on the seabed in Scapa Flow, Orkney. It is now hoped part of the torpedo, including the propeller, can be salvaged for display. The device was first spotted in February during a routine sonar survey by Sula Diving for Orkney Islands council. David Sawkins, the deputy harbour master, said: "Although it posed minimal danger to shipping, our responsibility it to operate a safe harbour and, it was likely to contain live explosives, the prudent course of action was to alert Royal Navy bomb disposal experts". The Royal Oak went down on 14th October 1939 with the loss of 883 lives.

Daily Telegraph, 7th April 2016

Guidance on Security for engineers and technicians

The Trustees of the Engineering Council held a reception to launch its "Guidance on Security for engineers and technicians" hosted by The Rt Hon John Hayes MP. The event was held on 19th May at the Terrance Pavilion, House of Commons at Westminster.

As the regulatory body for the engineering profession, the Engineering Council, with the support of the Centre for the Protection of National Infrastructure (CPNI) and the professional engineering institutions, have developed this material in order to provide guidance for engineers and technicians on their role in dealing with security, and their associated responsibilities to society.

The Rt Hon John Hayes MP provided a keynote address and Engineering Council Chairman, Rear Admiral Nigel Guild CB Deng CEng FREng, introduced the guidance and outline its importance to the engineering profession.

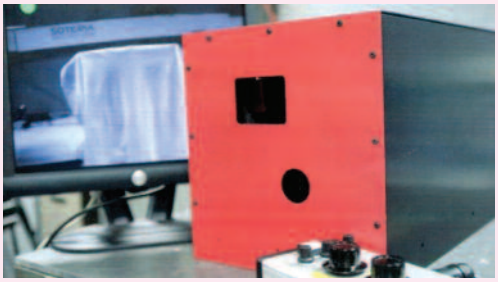
Terry Morgan CBE CEng FREng, Chairman of Crossrail, provided insight into the importance of security for employers. The Head of CPBI emphasised the link between the guidance and ongoing national infrastructure security.

Could British invention foil terror bombs?

Europe has now suffered two major terrorist attacks in under six months. A total of 162 people were killed in the Paris and Brussels attacks in November and March respectively, not including the attackers. Inspired and directed by so-called Islamic State (IS), they detonated a total of eight bombs, using powerful explosives, reported but unconfirmed as TATP (triacetone tri-peroxide). Specifically, is there a device on the market that could be installed, without exorbitant cost, to detect the presence of explosives in a crowded space such as an airport or station?

Scientists at Loughborough University, in the East Midlands, believe they have invented the answer: an explosive residue detector that uses cutting-edge laser technology. The equipment in question, dubbed the ExDetect, is neither discreet, quiet nor blessed with any great aesthetic appeal – but, according to Professor John Tyrer, it is non-intrusive and could be just what is needed to save lives. "I'm sorry to say, but at the Brussels attack, this would have instantly sorted out the terrorists before they came into the terminal, and similarly the concert in Paris," he says. "If it had been on the doors there, it would have stopped people getting in."

A microscopic amount of Semtex 1A, a high explosives, is dabbed onto a T-shirt as a test. To the naked eye, it is almost invisible – but from a large red metal box mounted on a portable steel trolley, an ultra-violet laser beam flickers on to the white cotton surface of the garment. Immediately, a warning flashes up on the display monitor. The word "detected" appears in bold red letters, and a yellow circle highlights an illuminated red patch where the Semtex has touched the T-shirt. In practice, says Professor Tyrer, if the device was deployed at, for example, an underground railway station, a silent alarm would alert an operator, prompting the ticket barriers to automatically close and bringing officials to carry out manual checks using a swab stick.



Judging by the pattern of recent events, most suicide bombers would probably then detonate their device, but Professor Tyer points out that at least the bomber would have been prevented from boarding a crowded train. "Explosives are sticky", says Professor Tyrer, "they leave fingerprints everywhere, even days later, and the ExDetect can find particles that weigh just millionths of a gram."

Professor Tyrer and his team, from the University's Department of Mechanical Engineering, have spent 15 years developing this technology, at a cost of nearly £4million. Each laser box, or "head" as it is called, costs about £250,000. To effectively scan cargo from 360 degrees, he says, it needs two such devices aimed at an oblique angle.

The Department for Transport said: "We keep security under constant review, but for obvious reasons we do not comment in detail on specific measures.

Extract from report by Frank Gardner, BBC security correspondent, BBC News, 13th April 2016.

Tianjin Blast investigators' report

Chinese investigators have identified 123 people who were responsible for the Tianjin warehouse explosions on 12th August 2015 (see *Explosives Engineering* September 2015) that killed at least 165 people and caused direct economic losses of 6.87 billion yuan (US$1.1billion). Another 49 people, including 13 from Tianjin Ruihai International Logistics Co Ltd (Ruthai Logistics), owner of the warehouse, have already been put under "coercive measures" in line with the law, a State Council investigation team said in a report issued in February 2016. "Coercive measures" may include summons by force, bail, residential surveillance, detention and arrest.

After five months of investigation, the team concluded that the disaster – "an extraordinarily serious work safety accident" – was caused by the ignition of hazardous materials that had been illegally stored at the site. The fire started in a container through auto-ignition of nitro-cotton due to vaporization of a wetting agent during hot weather, the team said, adding that when the fire spread it ignited other chemicals, including ammonium nitrate. It said Ruihai Logistics had "illegally built a freight yard of hazardous materials, conducted illegal operations, illegally stored hazardous material and their safety management procedures were inept." The company's executives were found to have exploited their connections and bribed local officials to get approvals, it added. The explosions damaged 304 buildings, 12,428 cars and 7,533 containers.

Extract from Shanghai Daily February 2016.

Fireworks blaze leaves 100 dead at Indian temple

More than 100 people were killed and nearly 400 hurt when a fire swept through a Hindu temple in Southern India during an unauthorised fireworks display. A spark ignited a separate batch of fireworks that were being stored at the Puttingal temple complex in the village of Paravoor in Kerala state. Thousands of people had been packed into the complex when a big explosion erupted at around 3.am, officials said. The blaze then spread quickly through the temple, trapping devotees inside.

Daily Telegraph 11th April 2016.

Action on explosive weapons under Big Ben:

A demonstration of landmine and IED disposal was held with the first mine-hunting drone flying on Speaker's Green, House of Commons, on 21st April 2016.

The allure of a mine-hunting drone flying in Parliament was too much for MPs Peers and their staff. Despite being the Queen's Birthday and the day the US President arrived, a record number of parliamentarians came to see the latest in UK technology and techniques in clearing explosive weapons, including the innovative drone, and to try for themselves some of the equipment under the shadow of Big Ben.

The focus of the event, organised by the All Party Parliamentary Group on Explosive Weapons, was a serious one. Explosive weapons are still being used indiscriminately around the world with incidents such as Ankara, Brussels and Paris hitting the headlines, but every other day innocent people in countries like Syria, Iraq, Nigeria and Libya face the horror of IEDs. The event had to highlight the humanitarian impact of explosive weapons and the UK's leading role in mitigating this impact.

Bringing the danger to life for the parliamentarians were two of the UK's leading IED mitigation companies – Optima Group and Blaythorne Group, the drone is the result of a collaboration between Drone-ops ltd and Cobham Technical Services.

Optima's Jim Scott and Taff Parnell spent the day describing to the parliamentarians their experiences of dealing with IEDs and training local people in Iraq, while the Blaythorne team and Steve Wisbey from NIC had fun dressing them up in bomb suits and letting them drive the remote unmanned ground vehicle (UGV). Sadly even the Minister was not allowed to try and fly the drone.

The approach of the APPG is that the problem of explosive weapon usage needs an holistic approach and so the world of research was represented by Kings College London centre for informatics, who are pioneering a way to detect the explosive content of a device, the Royal British Legion Centre for Blast Injury Studies at Imperial College whose ground breaking research on blast victims directly led to the survival of many of the Paris and Brussels victims, and Action on Armed Violence publishers of the hard hitting report 'Unacceptable Harm', and finally, the APPG's media partner the Counter IED Report.

Many people will remember the iconic photograph from 1997 of Princess Diana on an International Red Cross visit to Angola where she visited a mine-field – so HALO Trust came along to the Green to demonstrate the traditional methods of digging up legacy landmines.

Roger Mullin MP, Chairman of the All Party Parliamentary Group on Explosive Weapons, who hosted the event on Speaker's Green said"The demonstration event was designed to bring home to my political colleagues some of the horror explosive weapons cause to innocent people and to those whose job it is to deal with the weapons and the aftermath of their use.

"It is my personal belief that if politicians around the world can work together on this appalling issue, we can make a huge impact in saving people's lives and helping lift many people out of poverty and deprivation."


APPG Chairman Roger Mullin MP and Deputy Speaker of the House of Commons Lindsey Holye MP hear about Counter IED work from Jonathan Shaw, chairman of Optima Group

Foreign Office Minister Tobias Ellwood watches the drone being put through its paces.
Page7 Photography – who captured the event for posterity in video and image.

Foreign Office Minister Tobias Ellwood MP, is a staunch supporter of the work of the APPG – he stressed the UK's commitment as a two prong approach "Our approach has been two-fold; one has been to support organisations to remove those explosive weapons, those landmines, those IEDs, to make the land safe; and the second is education - making people aware of the dangers they might face.

Shadow Foreign Secretary Hilary Benn MP congratulated the APPG on organising the event, "It is wonderful to see all the organisations taking part today, some using very, very old techniques, and some really modern, cutting edge technology."

The Speaker of the House of Commons, The Rt Hon John Bercow MP, has been a fervent advocate on the issues since the creation of the APPG: "It seems now that every other day we hear about some atrocious event involving a suicide bomber or IED. The incidents in Paris and Brussels are very close to home, but for people living in places like Syria, Iraq or Northern Nigeria, they are a part of daily life.

"The UK is at the forefront of the global effort to combat the threat of these weapons, and coping with the dreadful aftermath when these weapons do find their target.

"I am delighted to be able to add my support to this effort and to see my colleagues in both Houses come and learn about this valuable work."

Sadly Mr Bercow could not attend the event but the Rt Hon Lindsay Hoyle MP, Deputy Speaker came in his stead, along with the Deputy Speaker of the House of Lords The Lord Dear.

Participating organisations

Drone-Ops Ltd – a small innovative UK R&D company who have developed the first ever mine-hunting drone.

Cobham Technical Services Ltd – their Amulet mine detector is integrated under the drone.

Blaythorne Group - an independent company providing security consultancy, training and equipment exhibited some of the equipment and protective gear designed and made in the UK.

Optima Group – a British company created to defend civilians and security forces from explosive devices set up a diorama showing their instructors delivering training to MINUSMA Forces in Mali and an illustration of Sinjar in Iraq and explained how IEDs were deployed and countered.

NIC Instruments - develops equipment to support organisations involved in the defeat of Improvised Explosive Devices and brought along their remote control disrupter.

Kings College London – The Centre for Robotics Research demonstrated the sensors they have developed, which use bursts of radio waves to sense the presence of explosives.

Action on Armed Violence – has a central mission: to carry out research and advocacy in order to reduce the incidence and impact of global armed violence. They define 'armed violence' as the intentional use of force – actual or threatened – with weapons, to cause injury, death, or psychological harm.

The Counter IED Report – The APPG's official media partner is a specialist, subscription-based publication, which serves as an information source to communicate the latest developments in the fight against the IED threat.

Royal British Legion Centre for Blast Injuries Studies - was established in 2011 to address the disabling injuries of conflict. CBIS is comprised of the unique collaborations of civilian engineers and scientists working alongside military doctors.

The HALO Trust – one of the biggest and most respected mine-action charities in the world demonstrated how land-mines are traditionally cleared.

Nigel Ellway is the Head of Secretariat for the APPG on Explosive Weapons.On leaving the public sector in 2011 he created the APPG on Landmines which he co-ordinated until the 2015 election. He is the founding director of the international political communications consultancy Lynch-Pin Associates.

For more information about this event or for interviews with any of the participants please call: Nigel Ellway on 07586 329335 http://appgexplosiveweapons.co.uk/

Conferences/Exhibition Diary

HILLHEAD 2016

Hillhead Quarry, Buxton, Derbyshire, 28th to 30th June 2016

Three day international live-demonstration show for the quarrying, recycling and heavy construction industries.

Further information: Harvey.sugden@gmj.co.uk, www.hillhead.com

EARLY CAREERS IN WEAPONS AND EXPLOSIVES SYMPOSIUM 2016

Oxfordshire, 5th to 6th July 2016

Further information: earlycareerssymposium@gmail.com

ORDNANCE, MUNITIONS AND EXPLOSIVES SYMPOSIUM

Cranfield University and Defence Academy of the UK, Shrivenham, 1st to 2nd November 2016

Further information: www.symposiaatshrivenham.com

UK SECURITY EXPO

Olympia, London, 30th November to 1st December 2016

The global security showcase: design, secure, respond.

Further information: info@uksecurityexpo.com

SAFEX CONGRESS XIX

Helsinki, Finland, 15th to 20th May 2017

Further information: secretariat@safex-international.org

EFEE 9TH WORLD CONFERENCE

The Brewery, Stockholm, Sweden, 10th to 12th September 2017

World conference on explosives and blasting

Further information: info@efee2017.com, www.efee2017.com

In a Flash
A. G. Bex
OBE

Your age:
47

Occupation:
Army Officer.

Current position:
Commander 29 Explosive Ordnance Disposal and Search Group.

Responsibilities in job/work activities:
Preparation, Generation and Command of force elements in delivery of EOD, Search, Ammunition Technical Support and Military Working Dog capability on operations across the globe.

Why are you involved in IExpE?
To represent the interests of the Defence members in the Institute and progress my own professional development.

What are the benefits for you of the IExpE?
Exposure to wider aspects of explosives engineering and interesting people in the explosives industry. Access to professional registration with the Engineering Council, with support and mentoring from other members.

What alternative career might you have followed?
Helicopter pilot or (as my wife commented) a life on the stage. Sadly the nearest I get is the odd karaoke performance!

Who do you most admire on the current world stage and why?
Tim Peake. I'm in awe of the determination and self sacrifice he has shown in achieving his goal of space travel. His exploits from the International Space Station are a true inspiration to the next generation.

Who would you most like to meet from any century and why?
Alfred Nobel. As well as inventing dynamite his foundation of the Nobel Peace Prize was truly far-sighted and still has a tremendous positive impact on the modern world. An amazing legacy.

What are your favourite activities/hobbies?
Mountaineering and cycling.

What is your ideal holiday?
Mountains, sea and rivers with great food and wine.

What is your favourite type of food?
Steak cooked medium rare served with tasty vegetables and a decent red wine.

IExpE Journal calls for papers

Deadline for September 2016 issue is July 31st 2016. 1500 - 3000 word articles and papers will be considered for publication and should be accompanied by digital illustrations eg. photographs, drawings and tables.

E mail the Editor: editor@iexpe.org

Explosives Engineers Educational and Research Trust

The Trust was formed in 1982 to advance the theoretical and practical education and training of persons engaged in the explosives engineering industry by the provision of training courses and the publication of technical, educational and informative material together with the financing of research and the provision of scholarships to assist with courses of study in the field of explosives engineering.

For more information and how to apply for a grant visit:
info@explosivesengineerstrust.com

To advertise your company's products and services in the Journal please contact Gordon Hunt Telephone: +44 (0)1726 832594 Email: design@gordon-hunt.co.uk

IExpE Merchandise

Polo shirt	£18.99	Porcelain mug	£6.99
Micro fleece Jacket	£27.75	Ceramic mug	£5.25
Fleece Jacket	£25.65	Themo Sports mug	£12.50
Soft Shell Jacket	£38.49	Coaster	£2.99
		Coaster set (x 4)	£5.25

Prices quoted are excluding postage.

Orders can be placed with Emille via email at craftycraftsales@gmail.com or on 07973 618827


Vision
Manage your project, not your website.
Spend less time configuring projects
Share your data with anyone. Not everyone.
Visualize this: Powerful interactive reports.
Minimate Pro
Instantel