



# INTERNATIONAL BALLISTICS SOCIETY

The International Ballistics Society (IBS) promotes the science of ballistics internationally. The IBS provides for technical interchange via an International Symposium on Ballistics and provides professional development for its members by providing opportunities for publication, short courses, student programs, and other activities to promote career development.

## Letter from the President



Dear Colleagues and Society Members,

Welcome to our Second International Ballistics Society Newsletter! Since the first newsletter was distributed, the paper selection meeting was held in Miami. Dr. Ernie Baker, Dr. Doug Templeton, Sam Campagna, and Kari King deserve a special thanks for making it a great success. The selection process went very smoothly and we are on track to have a great meeting in Miami this coming September. I hope to see all of you there.

We owe a special thanks to the NDIA. General Farrell, Sam Campagna, and Kari King have done several things to help our

society. First, they have released all of the proceedings that they control to the society. In the future, the society will maintain the rights to the papers. We have a group of volunteers working to get the papers into searchable pdf format. There are a number of steps involved and for the older sets of proceedings we are not able to get 100% optical character recognition. So, some of them won't be perfect, but they will all be readable. We are working now to populate an online store with the proceedings and the individual papers. We expect to have this complete by 1 May. In the meantime, look at the store occasionally. You will be able to see our progress as more and more papers become available.

I'm sure that you have started to become familiar with the ballistics.org web site. You can see that we continue to make progress. However, you can't see everything yet. Like the effort to make past proceedings available, we are also pursuing other developments. Our Nominations Committee, headed by Dr. Ian Cullis, has developed an elections procedure that will be used to elect the several board positions that will become vacant this year and we plan to implement an elections module on our website. Our goal is to allow members to vote electronically. The results of the board elections and the new slate of officers will be announced during the 26th ISB.

Our membership committee, chaired by Clive Woodley, has polled our corporate members in an effort to determine how the society can provide value to them. The support that we receive from our corporate members is extremely important and we want to do our best to be responsive to them. Not only do we benefit from the dues that we receive, but we also benefit by having the names of these companies associated with the society. Please look at the information on the web page and check out the advertisements that these companies have in this newsletter. If you are looking for a partner or a supplier, I am sure they would love to hear from you.

At the time of this letter, we have almost completed all of the paperwork needed to file for our status as a 501(c)3, not-for-profit, charitable corporation. We are developing a special membership category for universities. Our goal is to encourage participation in the society, especially our symposia, by students and faculty. We are finalizing plans for a student program. The student program will encourage the submission and presentation of papers prepared by university students. We plan to offer a stipend and other benefits to help students attend to make their presentation. We are just starting to develop ideas for an education program. We are also finalizing the creation of an outreach committee that should help us spread the work about the society and relevant events to many of our colleagues around the world.

Except for contracting with companies for specific services such as the website, the work of this society is performed by volunteers. We currently have at least a dozen volunteers who are routinely providing support to the society. All total, we have 40 or more individuals providing volunteer support as needed. I continue to be amazed by the performance of these individuals. They are devoting considerable time and effort in support of the society. Please join with me in thanking each of them for their contributions.

Work has been intense, but we have found opportunities of a lighter nature as well. We worked with a company to design a polo shirt and attractive mug with the society logo which will be made available via the online store. Normally, orders will be filled by shipping them to you directly. However, we plan to provide an option for you to place your order and pick up the shirt(s) at the ISB, saving you the shipping cost.

I hope that this brief summary simply helps keep you aware of the progress being made. If you like where we're headed, become active. It can be as simple as inviting a colleague to join or asking your company to become a corporate member.

Sincerely,  
Jack Riegel

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## Help Needed from Members!

1. **Recruit new members** - spread the word and get your colleagues to join
2. **Get involved** - see the website for a list of committees and projects with contacts
3. **Send or post cool photos** - we want good photos showing ballistic events in each field
  - Interior Ballistics
  - Exterior Ballistics
  - Launch Dynamics
  - Vulnerability
  - Terminal Ballistics & Impact Physics
  - Explosion Mechanics

Please upload photos at  
[www.ballistics.org](http://www.ballistics.org)

*Remember to be responsible with sensitive or restricted information!*

# 26<sup>th</sup> International Symposium on Ballistics

*On Track with Great Abstract Submissions*

The paper selection meeting for the 26<sup>th</sup> International Symposium on Ballistics (ISB) was held on the 6<sup>th</sup> – 8<sup>th</sup> December 2010 at the EPIC hotel in Miami, Florida, USA.

The meeting was hosted by Sam Campagna and Kari King from the NDIA with Ernie Baker and Doug Templeton, the symposium co-chairs, acting as facilitators.

The review of abstracts is one of the most important jobs in organizing a symposium, since the quality of the papers defines its standing in the ballistics community.

This paper selection meeting, however, had an additional honor in being the first held under the auspices of the International Ballistics Society. Nevertheless we followed the process laid down by the International Ballistics Committee (IBC) and the meeting was a great success.

Members of the Society who are considered experts in their fields reviewed the submitted extended abstracts. Those who could not attend the meeting in person also review abstracts electronically and we try to have three independent reviewers for each paper in each of the technical areas of the symposium. The reviewers mark each abstract in terms of quality and suitability for a poster or oral presentation, taking note of the author's preference as much as possible. They also identify papers that might make good presentations for the general sessions. The reviews are quite intensive and you 'can't hear a pin drop' during them! That said it is great fun.

We are always interested in having new Society members become involved in abstract review. If you wish to take part then please contact the organizers of the 27<sup>th</sup> ISB in Freiberg, using the link on the Society website.

In the Miami review there were 23 experts from 7 countries and we had 298 abstracts from 30 countries to review. At the end of the review we had rejected only 13 papers, with a program of 224 posters and 61 oral presentations.

We encourage a wide range of papers, from work in progress through to journal quality papers. At the 25<sup>th</sup> ISB we published 19 journal quality papers in a special issue of the Journal of Applied Mechanics, with Bo Janzon as its guest

editor. This will be repeated for the Miami Symposium and Bo held a meeting of reviewers to discuss the schedule for the review of the 40 submitted papers. This is a tremendous achievement!

The final task of the meeting is to visit the symposium site and review the arrangements. In Miami we simply had to cross the road to the Hyatt Regency hotel and conference center. The symposium venue is superb and able to cater for our every need. There are outside restaurants and bars that sit on the bank of one of the many canals in Miami. The reviewers are shown below, during our tour of the Hyatt Regency.



Some of the old hands at these meetings, especially Manfred Held, ask some very probing questions of the hotel staff, Sam and Keri, about the refreshments, poster stands and many things you would never think about! In Manfred's case this is a service we will sadly miss in the future.

Few of us realize how much hard work Sam and Kari put into finding a venue and working the almost endless list of domestic arrangements to ensure the symposium runs like clockwork. They both deserve our unreserved thanks.

The 26<sup>th</sup> ISB will I am sure be a tremendous success and we look forward to welcoming you in September.

## Dr. Manfred Held Will Be Deeply Missed

Many of our members knew Manfred personally. To our knowledge, he is the only person to attend every International Symposium on Ballistics to date. His passing is an end of an era.

He routinely participated in the paper selection process. In fact, many of us last saw him in December at the paper selection for the upcoming symposium. During recent symposia, he has offered lectures immediately preceding the conference. He was scheduled to do that again at the 26th ISB.

Prof. Dr. Manfred Held was the first person in this society to be named a Ballistics Science Fellow. He was quite proud of that fact and started using a version of his IBS Membership Card as his calling card. For everyone in attendance at the 25th ISB, I am certain that you could see the emotion in his face when he received the honor. That evening, he brought me a beer and gave me a "bear hug" as he thanked me. I will long remember that moment.



I met Manfred in the 1980's and came to know him quite well beginning with the 12th International Symposium. It goes without saying that Manfred was a major contributor to the science of ballistics. He was also a major contributor to the community of ballistics. He was always a gentleman, always anxious to help, and always interested in teaching. He will be deeply missed.

The IBS intends to create a Scholarship Fund in his name. I also intend to make arrangements for the lectures he planned for the 26th ISB to be offered by a few members of the society. I have a copy of his slides, so I expect we can provide a commemorative handout for everyone who attends the lectures. The NDIA has agreed that they will make a contribution to the scholarship fund based on the revenues from the fees for the lectures. In addition, we will create a feature on the website where members can donate to the scholarship fund if they so desire.

*Written by Jack Riegel*

## New Ballistics Science Fellows

The position of Ballistics Science Fellow is one of honor within the International Ballistics Society. It is awarded by the Society's members to those who have distinguished themselves within the Ballistics Community through outstanding and numerous significant contributions.

Dr. Louis Zernow is awarded this honor for providing significant leadership beginning as a Founding Father of the International Symposium on Ballistics out of which the Society itself has found its roots. Furthermore, in addition to his own many significant scientific contributions to Ballistics, not the least of which are key findings related to shaped charges and armor, Dr. Zernow has long encouraged many others to advance fundamental ballistics research.

Dr. Pei Chi Chou is awarded this honor for his significant guidance and encouragement towards developing and nurturing many young researchers within the Ballistics Community some of whom have gone forward to become key community members. Dr. Chou's scientific contributions to ballistics are well represented not only within the proceedings of the International Symposia on Ballistics but also in many other venues.

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## Website [www.ballistics.org](http://www.ballistics.org) Continues to Offer More Tools

The International Ballistics **Society** was created in the wake of over 30 years of fantastic International **Symposia** on Ballistics, which occurred every eighteen months. One important objective of the Society was to create an environment whereby members could benefit more regularly through sharing of information. The Board of Directors emphasized the website as the most important first tool and thus approved investments for its creation. This has been a stepwise evolution as resources became available, as is always the case with new startup entities. Nevertheless, the expansion of website offerings has been faster than anticipated and there is more coming.

As reported in the last newsletter, the site had been set up to offer general information about the society, sponsors, ballistic fields and events. In addition, a "Members Only" section was developed to allow special privileges including registration for events, creating mutipost links, submitting messages and viewing projects, file archives, photos, and more.

The site has become an even more powerful

tool for the members over the past few months. The online store is "open for business" and offers individual papers from past symposia as well as complete proceedings. The hosts of all prior symposia have given rights to the IBS so that these papers may be offered online. Please be patient, however, as the process to have these loaded in a viewable and downloadable format takes time. Thanks to all prior symposia hosts for supporting this effort.

In addition, the website is refreshed regularly with new stories, articles and links related to ballistics. This includes short articles about our members and work performed by them and the institutions they represent. Examples are included later in this newsletter. We also include relevant news articles from around the world related to the science of ballistics. We encourage our members to submit candidate articles for consideration as well as to upload photos of interesting ballistic events.

What will you see next? In addition to more past proceedings and papers, the online store will begin to offer IBS logo items like polo shirts and mugs. In addition, board member elections will be managed electronically through a website module. The classified ads section will become more active allowing members to search for and offer related items. We expect more information to be posted for events and specialized courses offered in the area of ballistics.

The IBS website should be a useful tool that our professional and student members open regularly. In fact, you may want to create a desktop icon for the website so you remember to launch it when you get in to work.

### Did you know...

- *Isaac Newton (1642-1727) studied air resistance and concluded that it was proportional to the square of the velocity.*
- *The caliber 30 M2 standard projectile would fire over 40 miles in a vacuum if shot at a 45 degree angle. That is about 22 times the actual maximum range. (Hatcher's Notebook)*
- *Early attempts to characterize velocity as a function of distance relied on ballistic pendulums placed at various standoffs. The velocity at each distance was based on an average of multiple shots. Researchers initially didn't believe the velocities because they were confident that nothing could move faster than the speed of sound in air.*
- *One of the most important inventions, which enabled soldiers to fire cross bows or rifles effectively from horseback was the stirrup. Weapons could not effectively be used from horseback prior to that invention.*

## Membership Continues to Grow!

### Membership numbers

The membership of the IBS has grown steadily in its first year of existence and the IBS is sincerely grateful to all the members who have supported it by becoming Founding Members and, in many cases, Founding Lifetime Members. All types of Founding Member will receive a membership certificate on card in the post so it is vital to ensure your address details are complete and up-to-date on the IBS website.

The current membership of the IBS breaks down as follows:

Student Members	11
25 <sup>th</sup> ISB members	176
Ordinary Members	106
Lifetime Members	61
Senior Members	6
25 <sup>th</sup> ISB Fellows	4
Fellow Members	26
Emeritus	12
Corporate Silver	8
Corporate Gold	4
Corporate Platinum	4

New members are always welcome. Please encourage your friends and colleagues to join. You could also encourage your employer to join as a corporate member. The benefits available for corporate members are described later in this newsletter.

### Membership types and eligibility

The IBS Constitution defines several types of individual membership: Student, Member, Senior, Fellow and Ballistic Science Fellow. Whilst the eligibility for some of these categories is clearly defined, it was thought that some further guidance would be beneficial. We're sure that some of you would have been asking questions such as "What do I have to do to become a Senior Member?". The Membership Committee has been working hard to produce firm guidelines and these have now been approved by the IBS Board.

The following procedures and selection criteria have been adopted for electing Senior Members:

- The person must be a Member and have been continuously a Member of the IBS for at least 8 years
- In the founding years of the IBS, the criterion for a Senior Member should be that they have attended at least 6 ISB (a period equivalent to about 8 years), not necessarily consecutive
- Nominations may be made by the Member themselves, or an active Fellow, supported by at least 2 Fellows who are currently Members, together with the evidence
- Evidence is expected to include ISB attended, papers published in the proceedings of the ISB and papers published elsewhere on the subject of ballistics
- It is anticipated that acceptable criteria for serious consideration of the nomination would be attending ~50% of the ISB and having ~4 relevant papers published over the period

- If no evidence is provided then the nomination will be declined – evidence may be submitted by any of the nominees
- Nominations must be made to the Membership Committee
- The Membership Committee shall consider the nomination and make one of the following decisions (by majority vote) :
  - Decline the nomination, stating reasons
  - Request further information, which might include contacting other Members
  - Recommend the change in membership status to the IBS Board
- The IBS Board shall consider the recommendation and approve or decline it
- The change in membership status occurs at the next ISB that that nominee attends or, in exceptional circumstances, immediately with the agreement of the IBS Board.

Similarly, the following procedures and selection criteria have been adopted for electing Fellow Members:

- The person must be a current Senior Member or, in exceptional circumstances, a current Member of the IBS
- Nominations may be made by one Fellow who is currently a Member, and supported by two other current Fellows. As Fellowship is conferred for meritorious accomplishments, the Fellows must be from three different countries
- Nominations shall be supported by written evidence. Evidence is expected to include International Symposia on Ballistics (ISB) attended, papers published in the proceedings of the ISB and papers published elsewhere on the subject of ballistics
- It is anticipated that acceptable criteria for serious consideration of the nomination would be active involvement in the ISB/IBS for ~20 years, attending ~50% of the ISB and having ~10 papers published over the period
- If no evidence is provided then the nomination will be declined – evidence may be submitted by any of the nominees
- Nominations must be made to the Membership Committee
- The Membership Committee shall consider the nomination and make one of the following decisions (by majority vote) :
  - Decline the nomination, stating reasons
  - Request further information, which might include contacting other Members
  - Recommend the change in membership status to the IBS Board
- The IBS Board shall consider the recommendation and approve or decline it
- The change in membership status occurs at the next ISB or, in exceptional circumstances, immediately with the agreement of the IBS Board.

## Membership (Continued)

### First Senior Members

Following the adoption of these guidelines, the Membership Committee reviewed the list of members as of October 2010 and found that six members were eligible for election to Senior Member status. These names were recommended to the IBS Board which approved all of them. Therefore, the IBS is pleased to announce that the following Members have become Senior Members (the first such members in the IBS):

- Ernest Baker
- Zheng-xiang Huang
- Tony Russell
- Izak Snyman
- Xiao-bing Zhang
- Paul Locking

Many congratulations to all of them.

The IBS realises that a great many more members are eligible for Senior Membership. Any member who thinks they are eligible and wish to become Senior Members should compile their evidence, support from two existing Fellow Members and submit their case to the Membership Committee. If any member is uncertain on their eligibility then please contact the Membership Committee.

Similarly, there may be several members who think they may be eligible for Fellow Member status – any such member should follow the guidelines stated above. If any member is uncertain on their eligibility then please contact the Membership Committee.

### Corporate Member Benefits

An important part of the IBS is the involvement of Corporate Members. The Membership Committee has been working with a number of Corporate Members to define what benefits each corporate membership category should receive. Recommendations were made to the IBS Board which has agreed to the following Corporate Membership benefits:

- **Platinum** - Banner ad on the web site plus additional information (~600 words) about the company on the web site and links to a corporate page. Opportunity to place a full page advertisement within any newsletters that the IBS publishes at no cost. Four delegates (treated as individual members). Free downloads of up to 20 papers from previous International Symposia on Ballistics (ISB). Acknowledgement of IBS membership in ISB symposium brochure and website.
- **Gold** - Information about the company (~400 words) on the web site and links to a corporate page. Opportunity to place a half-page advertisement within any newsletters that the IBS publishes at no cost. Three delegates (treated as individual members). Free downloads of up to 10 papers from previous ISB. Acknowledgement of IBS membership in ISB symposium brochure and website.
- **Silver** - Information about the company (~250 words) on the web site and links to a corporate page.

Opportunity to place a quarter-page advertisement within any newsletters that the IBS publishes at no cost. Two delegates (treated as individual members). Free downloads of up to 5 papers from previous ISB. Acknowledgement of IBS membership in ISB symposium brochure and website.

- A corporate member can nominate any of its employees as a corporate delegate and these can be replaced at any time.
- Corporate delegates will be treated as full individual members of the IBS, including having the right to vote.
- Additionally, all corporate membership levels will be entitled to the following benefits on first joining:
  - An announcement will be sent to all IBS members informing them that the corporate member has joined.
  - Sending of a newsletter, produced by the corporate member, to all the IBS members - this letter should introduce the corporate member to the IBS members and should cover the ballistics activities of the corporate member.

Currently the Membership Committee, together with other members of the IBS, is considering what benefits would be appropriate for universities to help to encourage the next generation of ballisticians. We hope to announce details of these in the next newsletter.

### Refund Policy

The IBS Constitution makes no reference to refunds for membership payments. Therefore the Membership Committee has considered this matter, submitted recommendations to the IBS Board, which has agreed the following refund policy for corporate and individual membership fees:

- No refunds at all after 30 days of payment
- No refunds for individual term memberships, unless the member contacts the membership committee within 7 days of making a payment in which case a full refund less a handling fee of \$25 is paid (zero refund if the amount is negative)
- 75% refunds for lifetime individual memberships, unless the member contacts the membership committee within 7 days of making a payment in which case a full refund less a handling fee of \$25 is paid
- 75% refunds for corporate memberships, unless the member contacts the membership committee within 7 days of making a payment in which case a full refund less a handling fee of \$25 is paid
- In exceptional circumstances, the IBS Board has the discretion to vary this refund policy
- Refunds will be made only in US dollars.

# ***Electing Our Society's Board Members***

Ian Cullis

## **Nominations Committee**

The **Nominations Committee** (NC) is a standing committee of the International Ballistics Society (IBS) created under the Society's constitution and appointed by the Board of Directors.

The role of the NC is to recommend candidates for election to each position on the Board of Directors to be filled at each general election. I have been asked by Jack Riegel, our President, to chair this committee. I therefore wanted to let you know what the NC has been doing in preparing for the first election of Board members in September at the Miami Symposium.

The members of the NC are:

- Ian Cullis – Chairman
- Roxan Cayzac
- Pierre Chanteret
- Dan Pratt
- Ed Schmidt

Our first task has been to draft the Election Guidelines for Board approval. This is now complete and the final version of the Guidelines will appear shortly on the website under the Nominations Committee tab. Please have a look and let us know what you think.

## **Elections**

On the Monday before each Symposium the Society will hold its General Election to fill vacancies on the Board of Directors. Normally there will be three places to fill, although any additional vacancies due to resignations, etc. will also appear on the ballot.

Existing members of the Society will be able to vote electronically via an **election page** to be created on the website. We are currently building this new page with the help of our website developers – so watch

this space! We want every member of the Society to have an opportunity to vote. If we want the Society to thrive then every one of us should take part in the election.

New members, who join when they register at the Symposium, will also be able to vote, also electronically, although the details of exactly how this will work are still being finalised.

The results of the ballot will be announced by the President during the Symposium and the new Board will meet, to elect a new President and introduce itself to the Society on the last day of Symposium, before taking over their roles after the Symposium Review.

## **Nominations**

The most important task of the NC is to identify candidates to stand in the elections and serve on the Board. Ideally we are aiming for 3 candidates for each vacancy in the election. As we currently expect to have 3 vacancies to fill we are looking for at least 9 candidates.

We will be identifying and approaching members of the Society to stand in the election, but equally we are keen to hear from you if you wish to stand or wish to nominate a member who you think would be a good member of the Board – but please ask them first! You can email any one of us on the Committee, via the website and we very much want to hear from you.

We will keep you up to date on our progress towards the first election in September, so Watch this Space!

Remember:

***YOUR SOCIETY NEEDS YOU!***

***DON'T FORGET TO VOTE!***

## Member Profile:

### Interview with Dr. Doug Templeton



**Q: What are your current responsibilities in your position as Senior Technology Expert - Survivability for the US DoD?**

**A:** I lead and manage science and technology activities including basic and applied research; also provide direct support to acquisition program managers, providing the long term research strategy for Ground Systems Survivability. This includes interaction with Army, DoD, other Government agencies, academia, industry, and foreign sources. It also includes oversight on test and evaluation for research activities. We have a ballistics lab on site with 2 gun lines, with capabilities up to medium threats.

**Q: How did you get involved in survivability and ballistics?**

**A:** I came to TARDEC to work optics and laser protection. I was personally involved in, and responsible for the research, development, and fielding of the laser eye protection incorporated in all US combat vehicles unity vision systems since 1991. I gradually got more assignments in other areas of survivability, including signature management, hit avoidance, and systems integration, including emerging armor technologies. Working for Dr. Jim Thompson, I became involved with the development of new armors with the Army Research Laboratory (ARL), and modeling and simulation when Tim Holmquist (who was at the Army High Performance Computing Center at that time) became our staff scientist. When Jim retired in 2000, I became TARDEC's lead for armor development, including co-managing with ARL the FCS armor program. I became the Senior Technical Advisor-Survivability in March of 2010, after previously being the Deputy Associate Director - Ballistic Protection.

**Q: Will you briefly explain which areas of ballistic science are involved in your work?**

**A:** Primarily the areas of terminal effects, including experimental and modeling and simulation (M&S). I was a big advocate and driver for increasing M&S capabilities. Vulnerability is also an important area of ballistics for us.

**Q: How long have you been a part of the International Symposia on Ballistics?**

**A:** I attended my first ISB in Orlando in 2002 and have been active since.

**Q: Have you seen benefits from the ISB in terms of relationships, collaboration or scientific insight? Any examples or interesting stories to share?**

**A:** Certainly one of the biggest benefits to me personally

has been the opportunity to work with the best people nationally and internationally in the field of ballistics science - too many to completely list individually. I have had several collaborative efforts with experts both in the US and a few with those outside, including Valery and Egor Kartuzov. The greatest benefit may be the ongoing interaction on transparent materials, which continues to be an area of increasing interest. I head a working group of numerous researchers here in the US, who are involved in the entire spectrum from material characterization through ballistic behavior, including modeling and simulation. It is also interesting to track the emergence of technology and capabilities globally through the work presented at the conferences.

**Q: As Co-Chairman of the 26th ISB, what do attendees have to look forward to in September regarding the quality of papers/presentations? The venue?**

**A:** I sincerely believe that attendees to the 26th ISB will see an exceptional technical program with a broad range of very high quality oral and poster presentations. The selected venue is outstanding and allows us a lot of flexibility for the presentations and ample opportunities for offline discussions (which are sometimes the most productive part of these meetings). And... it is in Miami where it is sure to be warm and sunny!

**Q: What are some of the challenges as Co-Chairman of the 26th ISB?**

**A:** For my part the biggest challenge has been the time challenge of working the Symposium. Fortunately, I have an exceptional capable and gracious Co-Chair, Dr. Ernie Baker of ARDEC, who has carried more than his fair share of the load. Additionally we have outstanding support from NDIA (Ms. Kari King, Sam Campagna) and Jack Riegel, president of IBS.

**Q: Do you see the recent formation of the International Ballistics Society as offering more benefits beyond the Symposia? If so, how?**

**A:** Yes. The formation of IBS put a permanent recognized face to the science of ballistics, in all its myriad facets, much that way that SPIE does for optics.

**Q: What would you like to see offered by the Society that would help add value to the members?**

**A:** I think that one really good effort would be the identification, development, and advocacy of an objective basic through advanced educational program that members could use to advance their professional careers. I am not necessarily advocating that these all of these courses/classes be run by the IBS, but a comprehensive listing of what is available would be useful.

**Q: Do you believe the field of ballistics will continue to gain interest globally?**

**A:** Without a doubt – just look at the growth in attendance at ISB!

### UK Breakthrough in Material Testing

Many materials of interest to engineers and ballisticians are anisotropic, i.e. their properties are different in different directions. A classic example is the Titanium-Aluminium-Vanadium alloys, which are used extensively in the aerospace industries as turbine blades and by armourers because of their low density and high strength.

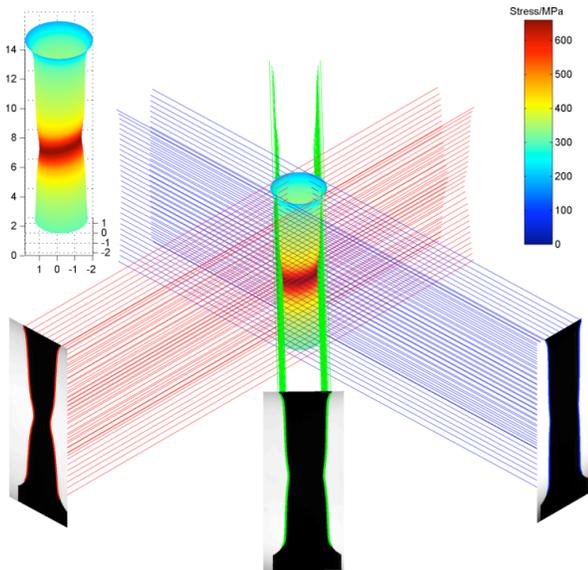


Figure 1. Experimental Arrangement

This anisotropic behaviour, however, makes testing of these materials problematic because the resulting non uniform deformation is often difficult to measure and analyse. Test specimens are usually either cylindrical or dog-bone in shape, with the latter favoured for anisotropic materials. However there are still issues with the interpretation of the measurements, since out of plane deformation, resulting in the specimen twisting and assumptions in the analysis do not always result in an accurate measurement of anisotropy and strength.

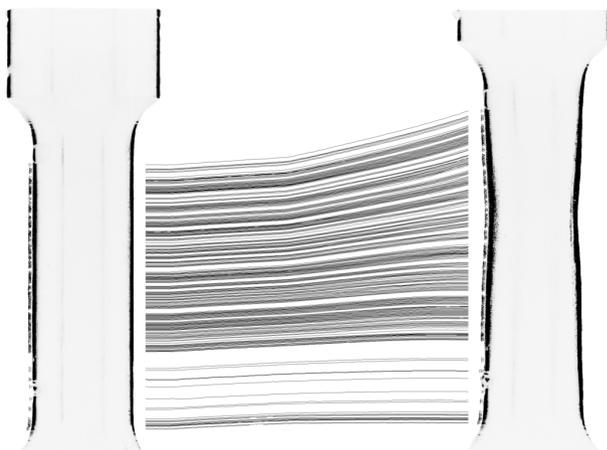


Figure 2. Measurement of specimen strain

Recent research in the Department of Engineering Science at the University of Oxford in the UK has developed an elegant solution to the testing of anisotropic materials, which can equally be applied to isotropic materials.

Matthew Arthington, as part of his doctoral research, has developed an optical technique which deploys three high speed cameras to accurately measure the time dependent deformation of a cylindrical specimen, figure 1. The method allows the accurate determination of the shape of the elliptical cross section that the specimen adopts because of the inherent material anisotropy. The aspect ratio of the ellipse is a measure of the material's anisotropy. Whilst developing the technique, Matthew realised that the surface machining marks on the specimen represented a unique set of reference points which could be used to directly measure the axial strain time history, figure 2. The radial measurements, combined with the load history, allowed the determination of an accurate stress-strain curve and measurement of anisotropy as functions of strain rate and temperature. In the case of the tensile Hopkinson bar it avoids the need to apply the standard wave analysis when determining the strain.

The optical record also provides the time dependence of the position and shape of the neck in the specimen, which is a rigorous test of a constitutive model and a challenge for any modeller!

The technique has also been successfully demonstrated in the Taylor test, where a cylindrical specimen is dynamically deformed when it strikes an anvil.

Overall this new technique provides a significant advance in the measurement of material properties and provides the experimental data required to further develop our understanding of the deformation behaviour and strength of anisotropic materials.

For more information contact:

Matthew Arthington: [matthew.arthington@eng.ox.ac.uk](mailto:matthew.arthington@eng.ox.ac.uk)  
 Dr Clive Siviour: [clive.siviour@eng.ox.ac.uk](mailto:clive.siviour@eng.ox.ac.uk)

#### References

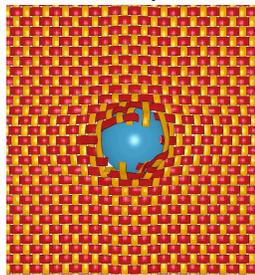
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# Predictive Modeling of Flexible Fabric Armor Impact using Multiscale and Probabilistic Computational Methods

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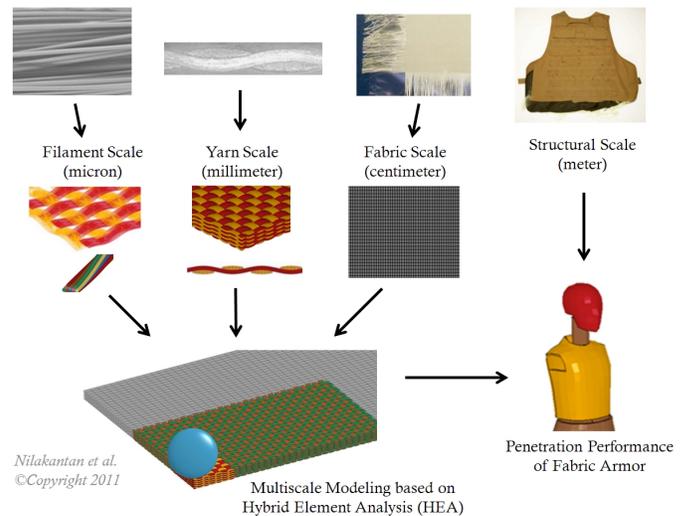
High-strength flexible woven fabrics comprised of Kevlar are used for personnel extremity protection and in body armor systems. The penetration performance of these fabrics is probabilistic in nature and can be described through the  $V_0$ - $V_{100}$  curve or Probabilistic Velocity Response (PVR) curve. Certain sources of variability, which can be statistically characterized, contribute to this probabilistic impact performance. For example the tensile strength of filaments and yarns is statistical in nature, while the filament geometry varies in cross-section along its own length. Similarly a small caliber projectile may randomly impact a fabric at a yarn cross-over or in-between the cross-over. A zone of mixed results (ZMR) is typically observed during the destructive experimental impact testing used to estimate the PVR curve.



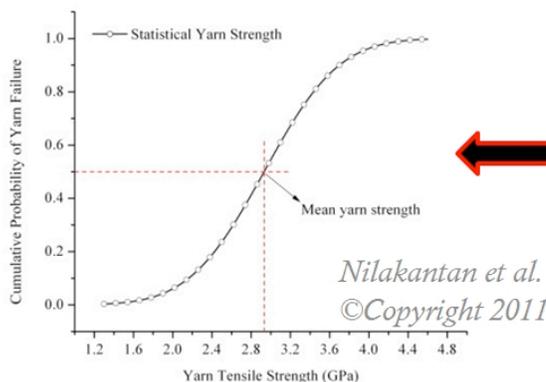
Traditional finite element (FE) analyses used to study the impact performance of fabrics are deterministic in nature and incapable of predicting the PVR curve. Recently we developed a probabilistic computational framework in order to predict the PVR curve using a FE analysis. Sources of variability such as the yarn tensile strength were first experimentally measured, statistically characterized, and then randomly mapped onto the individual yarns of the FE model. A series of impact simulations with different strength mappings were run, from which the PVR curve was estimated. The ZMR was successfully captured in

the simulation data. Other sources of variability such as projectile impact location, filament diameter, and inter-yarn friction can also be incorporated allowing both the isolated and combined effects of the sources of variability for various impact scenarios to be studied. Such predictive computational techniques help reduce the dependence on time consuming and costly experimental impact testing; moreover it serves as an efficient tool to design and test conceptual fabric architectures and material properties.

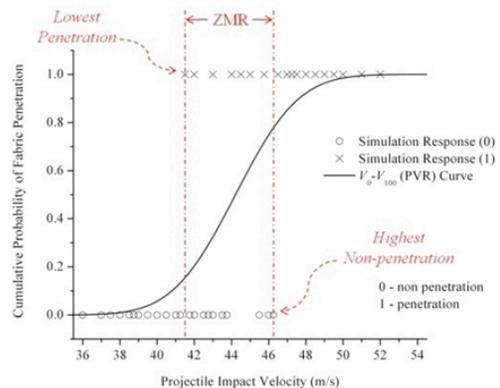
An important issue with computational simulations continues to be the computational requirements in terms of processing power and memory. Recently we developed a multi-scale modeling technique, the Hybrid Element Analysis (HEA), wherein the degree of modeling resolution decreases with distance away from the impact site, and the impedances are matched across all interfaces. This technique allows important filament-level interactions between the yarns and projectile to be captured at the impact site while at far-field regions a simpler membrane-level model is sufficient to capture the fabric impact physics. This drastically reduces the computational requirements compared to baseline fabric FE models. When integrated with each other, the combined multiscale-probabilistic fabric model serves as an important design and simulation tool.



**Experimental Data**  
 (statistical yarn strength)



**Simulation Results**  
 (fabric  $V_0$ - $V_{100}$  curve)



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