



# 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.

## PRESIDENT'S EDITORIAL

Dear Fellow Ballisticians,

You will be happy to know that things are moving forward for the 34th International Symposium on Ballistics to be held in Jacksonville, Florida. We are less than one year away from that symposium, which is May 19-23, 2025. This will be an exciting venue to discuss ballistics, including the central topics of interior, exterior, and terminal ballistics.

Recent world events are highlighting ballistics in a variety of ways. Perhaps noting two specific aspects are in order.

This year we had an exciting addition to this work in impact and large-scale terminal ballistics.

As has been discussed at previous ISB, small drones are surprisingly survivable. When traditional anti-aircraft warheads are used against them, the blast seems to have minimal effect and the drone is only destroyed if a key part is impacted by the warhead's small frags. One is reminded of the photographs of bomber aircraft in WWII where there were extensive holes in the plane, but they were still flying, because only the skin of the aircraft had been perforated and critical interior parts had not been struck. Though the media comments that drones are changing the face of battle are a stretch, it is clear that new methods of defending against or incapacitating drones need to be developed, so that the defense cost (i.e., defense resource dollar cost) is more in line with the relatively low cost to produce and operate the drone.

It may be that ballistics solutions will provide a solution. It may be that directed energy (such as lasers and high powered microwaves) will provide a solution. It may be that drone-on-drone activity will provide the solution (lots of mini aerial dog fights). Given the current conflicts using drones, it is likely the solution will be determined in the near future.



## Issue #13, June 2024

### CONTENTS

<b>President's Editorial</b>	<b>1</b>
<b>Looking Back</b>	
The 33 <sup>rd</sup> ISB in Bruges	4
Waffles, Beer and Chocolate	5
Gratitude Reception?!	8
Award Winners	9
<b>Inside the Society</b>	
Membership Analysis 2023	12
What's up with education?	15
IBS on LinkedIn	16
Update on Jack Riegel Student Awards	16
The IBS Online Store	17
<b>Scientific</b>	
Laboratory Review: Council for Scientific and Industrial Research (CSIR) South Africa	19
Safe Operation of Light-Gas-Gun with Hydrogen: The Case Study of the "Large Gun" at Fraunhofer EMI	29
Book Review	34
Did You Know...?	35
<b>Looking Ahead</b>	
34 <sup>th</sup> ISB in Jacksonville	37
Other Upcoming Events	40
<b>Corporate Sponsors</b>	<b>41</b>

## GET INVOLVED!

Don't just be a name on a list – be an active part of the scientific community!

See the website [www.ballistics.org](http://www.ballistics.org) for a list of committees & projects with contacts.

Second, the success of high-value air and missile defense systems is proving itself. These systems are either direct hit-to-kill or have traditional fragmenting explosive warheads. These are complex integrated systems, where radar tracking of threats is linked to fire-control systems that launch the missiles, and terminal guidance systems that effect the kill. These systems are able to destroy many types of high-speed incoming threats, including missiles and aircraft, through impact with either the entire missile body or fragments from warheads.

In both the examples, detailed ballistics studies can improve the success rate of these defensive systems. Through the use of experiments, analytical modeling, and large-scale numerical modeling, the defensive systems can be improved. Through these defensive systems successful demonstrations, there is a deterrence to further or future aggression, when it is seen that offensive systems are less effective or even ineffective.

With the recent IBS Board elections, two members of the Board of Directors were elected:

- Baoming Li, Ph.D. was reelected to the Board. He is a Professor of Nanjing University of Science and Technology and Director of the National Key Laboratory of Transient Physics. He received his Ph.D. in ballistics. He is an expert in ballistics and was appointed Chief Scientist of the China Academy of Ordnance Science in 2011. He is the standing Vice Director of the China Ballistics Society. He is an Executive Editor-in-Chief of Defence Technology.
- Frederik Coghe, Ph.D. was elected to the Board for a first term. He chaired the 33rd ISB in Bruges. He is a LtCol and is a Military Associate Professor at the Department of Weapon Systems and Ballistics of the Royal Military Academy (Brussels, Belgium). He has master degrees in Ballistics & Weapon Systems, Material Science & Metallurgy, and a PhD in Engineering. He does research in the fields of terminal ballistics and ammunition effects. He is also acting as a senior expert on survivability and lethality both nationally and internationally (STANAG 2920 and 4569, VPAM).



These board positions last for 3 symposia.



The officers of the society are elected by the Board from Board members. The officers till the next symposium are myself (James Walker) as President, Clive Woodley as Treasurer, and Frederik Coghe as Secretary. This is my second (and hence last) term as president. Clive is a previous president of the Society and this is his first term as treasurer. Frederik is new to the board but was willing to take on the secretary responsibilities. We will do our best in the oversight of the society.

Best wishes,

James D. Walker

President, International Ballistics Society





## LOOKING BACK AT THE 33<sup>RD</sup> ISB...

by Frederik Choghe  
Royal Military Academy, Belgium  
33<sup>rd</sup> ISB Chair

With the organisation of the 33<sup>rd</sup> International Symposium on Ballistics from October 16 through 20, 2023, in Bruges, the ISB came once again to Belgium, after having already hosted the 11<sup>th</sup> ISB in 1989 in Brussels. Choosing Bruges as the venue for the Symposium not only bode great opportunities for the non-scientific part of the Symposium (more on that in the part of Thomas Hartmann), but also proved to be an asset to the scientific part through the available conference infrastructure. Indeed, 'thanks' to the covid pandemic and the one-year additional preparation time, the ISB could be held at the brand-new Bruges Meeting and Convention Center (BMCC) right next to the city centre. The BMCC not only offers state-of-the-art conference facilities, but also a splendid, unique view on Bruges from the catering area.



*Bruges Meeting and Convention Center (BMCC)*

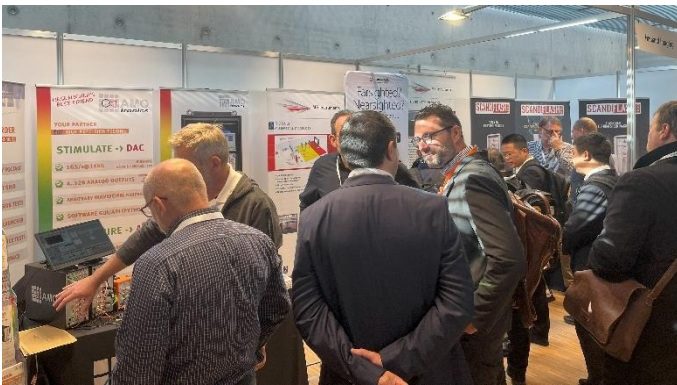
It should not come as a surprise then that Bruges turned out to be a success location regarding scientific output: almost 280 abstracts were sent in for review which thanks to the voluntary contribution of several review committees where all evaluated for their scientific merit. A big 'thank you' to all these volunteers assuring the scientific level of the Symposium. Of these initial abstracts, 239 final papers made it to the cut and were published in the Symposium proceedings. Due to the usual hick-ups (funding issues, visa, institution permissions...), more than 50 of these were orally presented at the Symposium and approximately 170 papers were presented as posters.



*Symposium information desk*

The Symposium itself attracted more than 380 participants in total from 34 different nationalities! By coincidence, 34 is almost the number of student participants and it was very nice to see that so many students have had the opportunity to attend the Symposium and network with professionals from all over the world working in the field of ballistics. As usual, the Symposium kicked off on Monday with five tutorials, not only in the regular fields of internal and external ballistics, vulnerability and explosion mechanics, but also with an in-depth course on applying machine learning to terminal ballistics! These tutorials turned out to be of particular interest to the Symposium audience as in total almost 120 tutorial registrations were received.

The oral presentations, besides the traditional welcomes of the President of the International Ballistics Society and the chairman of the Symposium, kicked off with two invited lectures, respectively given by LtCol Tom Simoons from the Royal Military Academy and Prof. Em. Morris Driels from the Naval Postgraduate School, illustrating how fire control for indirect fire evolved from World War I up to the most recent conflicts. After these, the oral and poster sessions continued on the regular topics of interior, exterior and terminal ballistics, launch dynamics, explosion mechanics, vulnerability and survivability and emerging technologies. Next to this, eight sponsors also supported the ISB and showcased their products and services during the coffee and lunch breaks.



*Exhibitors presenting their products during the breaks*



*Conference hall*

The symposium concluded with the presentation of awards. Congratulations to all.

Last but not least, the IBS again showed that the International Ballistics Society is a thriving

community that can count on its members for propagating the scientific knowledge in the field of ballistics, next to giving visibility to this intriguing scientific discipline which is often shielded, for obvious reasons, from views from the outside world. Thanks to the Symposium and the Society, worldwide visibility and collaboration in the field of ballistics can be improved. Another big 'thank you' to all of you who have contributed in making both the Symposium and Society a success! Looking forward to see you all in Jacksonville, USA, in 2025!

## WAFFLES, BEER AND CHOCOLATE – OUTSIDE THE ISB'S TECHNICAL PROGRAM

by Thomas Hartmann  
NUMERICS GmbH, Germany

The decision for a specific venue to host the International Symposium on Ballistics is traditionally not just based on the host's close relationship to the Society, but also on several other factors including the availability of leisure activities and their accessibility. And with respect to the latter, the city of Bruges was definitely a perfect match.

When Belgium is mentioned the first things you might think of are waffles, beer and chocolate. However, with its long and glorious history, especially Bruges has a lot more to offer.

In the late Middle Ages, the region around Bruges was one of the centres of the textile industry and long-distance trade in Europe and thus one of the birthplaces of early capitalism.

Therefore, Bruges became one of the economically and culturally richest cities in Europe at the time. Since Bruges was never destroyed by wars or large-scale fires, the medieval cityscape and historical buildings are very well preserved.



This is why the town centre was declared a World Heritage Site by UNESCO in 2000.



*Impressions of Bruges*

In Belgium, beer is not just a part of the culture but it is a cultural asset that is celebrated practically everywhere. So, “De Halve Maan” – one of the oldest breweries in Bruges (which, by the way, even has a 3.2 km long beer pipeline to the bottling plant in the outskirts) was sure a perfect location for the Welcome Reception. Alongside with delicious finger food one could catch up with colleagues and friends and directly get a first impression of the taste and strength of Belgian beer, which can have up to incredible 15 vol.-% alcohol.

The beautiful city can not only be explored on foot but also by boat, which we did on Wednesday’s afternoon excursion. All participants were divided into small groups and went on a guided tour on the canals that run through the city.

*Boat tour on the canals*

Seeing the city with its historic buildings from this different perspective was definitely something special. Luckily, contrary to the weather forecast, it didn't rain so that we had a pleasant and memorable experience.

The highlight of the social program is typically the Conference Dinner on Wednesday evening – and it definitely was a highlight in Bruges, too. As the venue the organizers had chosen the “Concertgebouw” (concert building), a cultural



centre which according to Trip Advisor is among the “1001 buildings you must see before you die”.



*Concertgebouw Bruges*

The evening opened with a performance by the Royal Military Academy’s student orchestra in the entrance hall. It was followed by a reception on the upper level – a nice warm-up for what was about to come.



*RMA student orchestra performance in the entrance hall*



*Reception outside the concert hall*

When the glasses were empty the crowd was led into the concert hall, where the winners of the Jack Riegel Student Award (which is traditionally presented at the Conference Dinner) were

announced. At that point probably most of the participants were still wondering where the actual dinner would take place – a question that was not only anticipated but also intended by the organizers: it was the “wow-moment” of the evening when finally the curtain was raised and revealed the dinner location set up on the stage in front of the audience.



*Dinner setup on the stage*



*Enjoying food and drinks*



*Belgian haute (chocolate) cuisine...*

After a delicious dinner, drinks were served at the bar and music was performed by the Royal Military Academy’s student orchestra, till at



about midnight we all went back to our hotel rooms – except for Frederik (Coghe), who had to stay a bit longer to help looking for a flute misplaced by one of the musicians...

In summary, the social program was (once again) very well organized and a great experience. A big thank you to Frederik Coghe and his team from the Royal Military Academy who made all this possible!

Finally, I would like to encourage everyone who was unable to attend the symposium to visit Bruges and experience the multitude of cultural and culinary highlights – including the famous waffles, beer and chocolate...

## GRATITUDE RECEPTION?!

by Thomas Hartmann  
NUMERICS GmbH, Germany

In addition to the Welcome Reception, the Boat Tour and the Conference Dinner the ISB social program also showed a “Gratitude Reception” on Thursday evening. However, this was marked with “invitation only” and some may have wondered what this was about.



*Bruges City Hall*

In fact, this reception was not really a part of the symposium itself. The Bruges city council generally invites the organizers of a convention or conference held in Bruges to a reception in the old town hall. Since this invitation includes up

to 100 people, the organizers decided to fill up the places that were available on top of the organizational team by those who had served as session or committee chairs, etc.

Hence, it was actually an event for the ISB organizers arranged (and financed) by the Bruges city council and which some participants were kindly allowed to take part in.



*Reception at the old Town Hall: Isabel Lahaye (left), Pieter Marechal (middle) and Frederik Coghe (right)*

The reception started with acceptance speeches by Pieter Marechal (city of Bruges alderman), Frederik Coghe (Symposium Co-Chair) and Isabel Lahaye (military Provincial Commander), followed by a historian giving an overview over the history of the building and the hall's (truly impressive) mural paintings.



*Alderman Pieter Marechal giving his acceptance speech*

Then – surprise – plenty of beer was served and after some chatting and drinking the reception was brought to an end.



## AWARD WINNERS

The International Ballistics Society assisted by QinetiQ and the South African Ballistics Organization awards the best authors in different categories during the International Symposium on Ballistics. The following authors were honored for their contributions to the 33<sup>rd</sup> ISB in Bruges...

### JACK RIEGEL STUDENT AWARDS

The Jack Riegel Student Award is awarded to the best papers from students presenting their work at the ISB (full eligibility requirements can be found on the IBS website).

At the 33<sup>rd</sup> ISB in Bruges the following students were awarded:

- **Christopher Lange**, Germany

Category: Explosion Mechanics

Title of Paper: *Impact Thresholds for the Reactions of Metals*

University: Helmut Schmidt University / University of the Federal Armed Forces Hamburg, Germany



*Jack Riegel Student Award presented to Christopher Lange (left) by Markus Graswald*

- **Bernd Dutschke**, Germany

Category: Exterior Ballistics

Title of Paper: *Aerodynamic Characterization, Flight Analysis and Limit-Cycle Stability for Artillery Shells Fired with High Elevation*

Institution: French-German Research Institute of Saint-Louis, France



*Jack Riegel Student Award presented to Bernd Dutschke (left) by Markus Graswald*

- **Enfa Fu**, China

Category: Interior Ballistics

Title of Paper: *Molecular Dynamics Simulation of Solvent Dynamics inside Nitrocellulose-based Propellants During Drying Process*

University: Nanjing University of Science and Technology, China



*Jack Riegel Student Award presented to Enfa Fu (right) by Markus Graswald*

- **Nicolas Reboul, France**

Category: Terminal Ballistics & Impact Physics

Title of Paper: *Study of the interaction between shaped charge jets and ERA flying plates*

University: Institut Supérieur de l'Aéronautique et de l'Espace – École Nationale Supérieure de Mécanique et d'Aérotechnique



*Jack Riegel Student Award presented to Nicolas Reboul (left) by Markus Graswald*

- **Gabriela Boneva, UK**

Category: Vulnerability

Title of Paper: *The Effects of Grazing Ballistic Impacts on Combat Helmets and Behind Helmet Blunt Trauma*

University: Cranfield University



*Jack Riegel Student Award presented to Nicolas Reboul (left) by Markus Graswald*

### LOUIS AND EDITH ZERNOW AWARD

The Louis and Edith Zernow Award in Ballistics is presented to the author(s) of the paper containing the best advancement made in the fundamental nature of ballistics and presented within the proceedings of the International Symposium on Ballistics.

At the 33<sup>rd</sup> ISB in Bruges the award went to

**A. Helte, J. Lundgren and J. Candle**

for their paper

*The interaction between a shaped charge jet and a single moving plate*



*Louis and Edith Zernow Award presented to Andreas Helte (left) by James Walker*

### ROSALIND & PEI CHI CHOU AWARD

The Rosalind and Pei Chi Chou Award for Young Authors is given to authors 35 years of age or younger at the time of the Symposium for the best original contribution to the ballistic sciences (full eligibility requirements can be found on the ISB website).

At the 33<sup>rd</sup> ISB in Bruges the award was presented to

**C. Franzmann**

for his paper



*Aerodynamic Characterization, Flight Analysis and Limit-Cycle Stability for Artillery Shells Fired with High Elevation*



*Rosalind and Pei Chi Chou Award presented to Bernd Dutschke (left) by Paul Locking*

**NEIL GRIFFITHS AWARD**

The Griffiths Award is presented to the author(s) of the paper judged to have made the most significant contribution to a shaped charge technology at the International Symposium on Ballistics.

At the 33<sup>rd</sup> ISB in Bruges the award was presented to

**H. Guo, T. Chen, S. He and Y. Zheng**

for their paper

*Study on the Forming Characteristic and Coherency of PTFE/Al Reactive Jet*



*Neil Griffiths Award presented to Huanguo Guo (right) by Ian Lewtas*

**SABO AWARD**

The South African Ballistics Organisation (SABO) Award gives recognition to the author(s) of the best poster as displayed and presented at the International Symposium on Ballistics.

At the 33<sup>rd</sup> ISB in Bruges the award was presented to

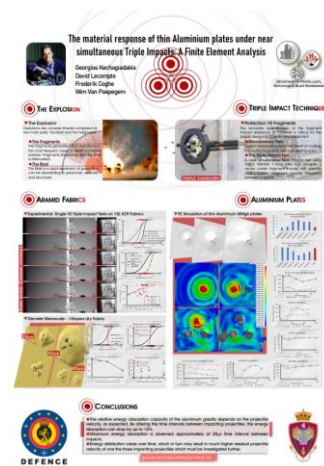
**G. Kechagiadakis, D. Lecompte, F. Coghe, W. Van Paepegem**

for their poster titled

*The material response of thin Aluminium plates under near simultaneous Triple Impacts: A Finite Element Analysis*



*SABO Award presented to Georgios Kechagiadakis (left) by Rudolf Gourws*



Congratulations to all award winners!

IBS MEMBERSHIP ANALYSIS 2023

by Clive Woodley  
Chair of the Membership Committee

The IBS has existed now for 13 years, having started in 2010. The first ISB (International Symposium on Ballistics) under the IBS was held in Beijing in 2010. It is fascinating to analyse the breakdown of the membership on the basis of country and member type. The former broadly follows the host nation, the latter is slowly trending upwards as members have been promoted. Each term, following the ISB and the dropping of people who have chosen not to continue their membership, the IBS membership is analysed. Further details are reported in the following paragraphs.

MEMBERSHIP BY COUNTRY

The top five countries, term by term (a term is approximately 18 months), are compared in

Table 1. The date is that of a few months after each ISB has taken place, when the membership has stabilized.

Several overall conclusions may be drawn from Table 1. In general, the total ISB membership has stabilized around 530-560 members. The USA has consistently been the country with most members except on two occasions, the first when the ISB was held in China and the second in 2022 when a lot of Chinese joined for reasons explained below. Germany and the UK have consistently appeared in the top five, with France, Israel and Sweden also having strong support.

Table 1 does show a few apparently anomalous statistics. The low number of total members in 2010 can be easily explained by it being the first year of the IBS. The apparent high numbers of members in 2012, in particular, and 2013 is explained by membership being compulsory if

ISB date country	1st	2nd	3rd	4th	5th	Total members
25th (2010) China	China (124)	USA (39)	Israel (22)	Germany (16)	Sweden (12)	297
26th (2012) USA	USA (317)	Israel (32)	Germany (32)	China (30)	UK (30)	647
27th (2013) Germany	USA (141)	Germany (94)	UK (40)	France (36)	China (34)	573
28th (2014) USA	USA (174)	China (47)	UK (45)	Germany (41)	France (22)	532
29th (2016) UK	USA (133)	China (63)	UK (62)	Germany (38)	France (22)	489
30th (2017) USA	USA (157)	China (134)	UK (47)	Germany (39)	Israel (22)	563
31st (2020) India	USA (123)	India (122)	China (62)	UK (36)	Germany (27)	550
32nd (2022) USA	China (291)	USA (125)	UK (40)	Germany (31)	France (27)	686
33rd (2023) Belgium	USA (125)	China (112)	UK (42)	Germany (39)	Belgium (23)	536

Table 1: Top 5 countries following each ISB



attending the ISB. Following the 27<sup>th</sup> ISB, people could attend the ISB without becoming members of the IBS, except for the 31<sup>st</sup> ISB which partly explains the large number of Indian members in 2020.

Note, however, that when membership is not compulsory to attend an ISB, it is cheaper to attend by becoming an IBS member.

The membership numbers in 2022, following the 32<sup>nd</sup> ISB, need further explanation. Clearly there was a substantial increase in Chinese members, particularly student members. An analysis of these indicated that many were from universities and institutes that previously had little to no prior involvement in the IBS. By coincidence, that term a Chinese person was standing for election to the Board and it became clear following the election that unprecedented numbers of votes had been cast. Subsequently, the voting requirements for IBS elections were amended so that only members of at least 12 months standing were eligible to vote.

This minimum membership requirement would help to ensure voters at least had some understanding of the IBS rather than joining and then being able to vote immediately. Following the 33<sup>rd</sup> ISB, it was apparent that very few of these new members renewed.

As expected, the IBS receives a significant boost in members from the country hosting the ISB. However, following the subsequent ISB, the number of members from that country decreases significantly (e.g. Germany over the period 2013-2014 and India over the period 2020-2022). The challenge for the IBS and the Membership Committee, in particular, is to try to encourage attendees to renew their membership.

Not shown by the data presented to date is the emergence of countries such as the United Arab Emirates which has grown from 0 members in 2020 to 6 in 2022 and then to 12 in 2023. Figure 1 shows the current breakdown in the main member countries.

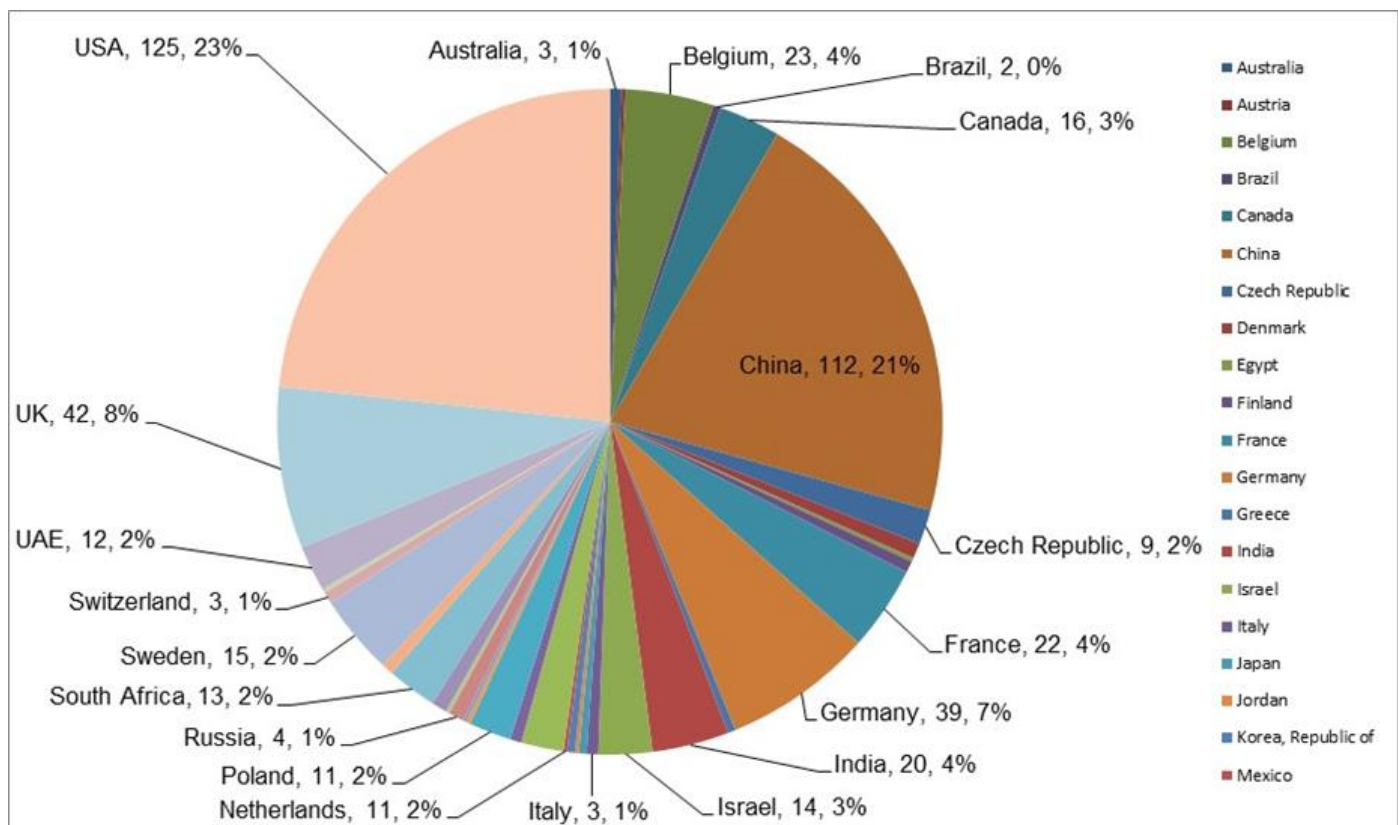


Figure 1: Country breakdown as of December 2023

**MEMBERSHIP BY TYPE**

The IBS has several different membership levels which include Student, Member, Senior, Fellow and Ballistic Science Fellow (BSF). Eligibility criteria for these levels are stated on the IBS website and so will not be repeated here. It is informative to analyse the number of members in each of these categories over the lifespan of the IBS – see Table 2.

It is greatly pleasing to see the steady increase in the number of Student Members. This can be partly attributed to the Jack Riegel Student Award which started with the 27<sup>th</sup> ISB in Germany.

There has also been an increase in the number of Senior members with significant jumps after 2017. This is mainly due to the eligibility criteria for promotion from Member to Senior, which includes a time-based criterion.

Members who have been a member since the formation of the IBS became eligible for promotion to Senior.

Promotion to Fellow is more difficult and requires demonstration of substantial knowledge and expertise in the fields of ballistics. But it should be expected that the number of Fellow members will slowly increase, based on the increased number of Senior members.

Promotion to BSF is much more difficult, rightly so because it is awarded only to those individuals who have distinguished themselves within the ballistics community. This award is typically given to individuals for numerous contributions to the science of ballistics, but also may be given for an outstanding contribution.

The breakdown of the current membership, according to membership type, is shown in Figure 2.

ISB date country	Student	Member	Senior	Fellow	BSF	Total members
25th (2010) China	3	241	0	33	1	297
26th (2012) USA	8	482	29	39	2	647
27th (2013) Germany	9	411	25	35	5	573
28th (2014) USA	32	341	30	32	7	532
29th (2016) UK	44	280	24	31	6	489
30th (2017) USA	82	313	36	34	6	563
31st (2020) India	39	330	56	28	6	550
32nd (2022) USA	239	208	100	37	7	686
33rd (2023) Belgium	85	194	116	38	7	536

Table 2: Top 5 countries following each ISB



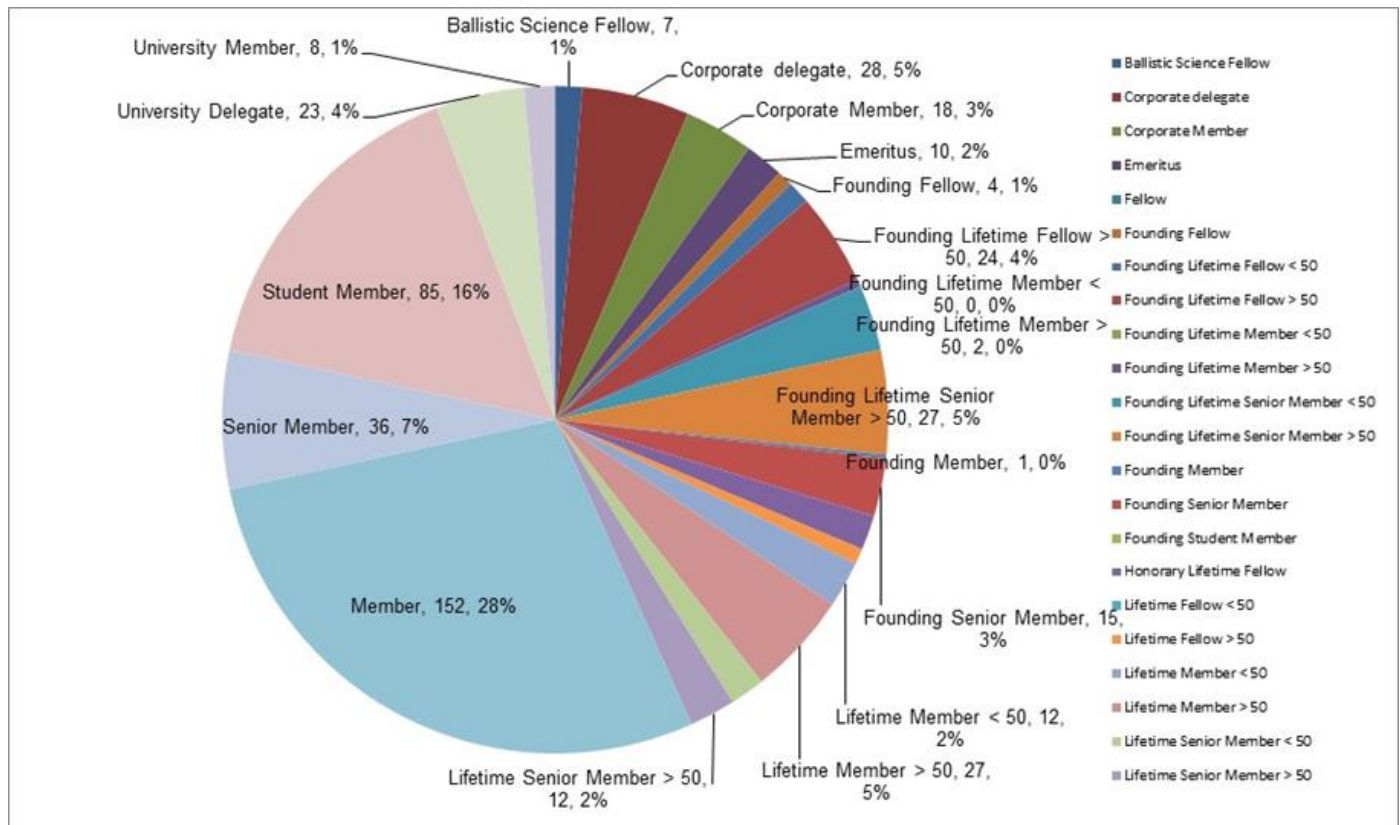


Figure 2: Membership type breakdown (not all grades are shown)

## WHAT'S UP WITH EDUCATION?

by Markus Graswald  
Chair of the Education Committee

Education has always been a major objective of the International Ballistics Society (IBS). It is the responsibility of the Education Committee (EC) providing tutorial courses and promoting career development of Society members. The committee consists of Sidney Chocron, Ian Cullis, David Davison, Markus Graswald, Zherui Guo, Dinesh Pal, Sebastian Wurster, and, as a new member, Shannon Ryan.

For the program of tutorial courses provided at the 33rd International Symposium on Ballistics (ISB) in Bruges in October 2023, we received an initial interest of 27 individuals and 11 course

proposals, from which we eventually selected five courses:

- EB101: Exterior Ballistics by Pierre Wey, from ISL, FR
- EM101: Explosion Mechanics by Peter Norton, Mike Harris, from Cranfield University, UK
- MT101: Shock Physics: Dynamic Behavior of Materials by Dr. John Borg, from Marquette University, USA
- TB201: Applied Machine Learning for Terminal Ballistics by Dr. Shannon Ryan, from Deakin University, AUS
- VS101: Protection and Survivability by Dr. Rachael Hazael and Dr. Kate Hewins, from Cranfield University, UK

This mix of introductory and advanced courses were attended by 114 people, which we consider

a great success and I would like to thank all those who attended, provided, or helped organize these courses. The participants' feedback survey resulted in a remarkable return rate of 65%, which will help us properly prepare future tutorial programs.

We will soon send a broadcast call for instructors and look forward to receiving course proposals. Can I ask you to forward this newsletter or the broadcast call to individuals or organizations, who are not currently involved in our Society? Thanks for your help!



*Tutorial Course at the 33<sup>rd</sup> ISB in Bruges (© M. Graswald)*

Last but not least, it may be good for you to know that:

- Attending courses or giving them as an instructor will support your promotion to senior or fellow member status of the Society.
- We do offer online training opportunities for IBS members on our website: IB101 Introduction to Interior Ballistics (as a video course split into ten sessions) by Dr Sebastian Wurster from Fraunhofer ICT in Germany and EB101 Introduction to Exterior Ballistics (via pdf presentation slides) by Pierre Wey from ISL in France. Just log in as a member and go to online learning.

We look forward to your feedback, so please contact us at [education@ballistics.org](mailto:education@ballistics.org).

Happy learning!

Dr. Markus Graswald  
(Education Committee Chair)

## IBS ON LINKEDIN

by Thomas Hartmann  
Chair of the Communications Committee

The International Ballistics Society has revived its LinkedIn account. News, updates and upcoming events will be announced there in parallel to the IBS website. Additional fun facts, jokes and other stuff will be posted occasionally. So, if you are on LinkedIn, follow us!

The account is maintained by Sabrina Wahler who will welcome feedback as well as suggestions for posts, stories or snapshots. Just send an email with the subject "LinkedIn" to [communications@ballistics.org](mailto:communications@ballistics.org).

## UPDATE ON JACK RIEGEL STUDENT AWARDS

by Markus Graswald  
Chair of the Education Committee

The International Ballistics Society (IBS) offers awards to students in each of the six ballistics science disciplines who produce the best papers. The award covers the registration fee at the symposium and provides 1000 USD towards travel and accommodation expenses. These awards were (re-) named after Jack Riegel reflecting and honoring his achievements for the Society, especially as its Founding President in 2010.



The student committee (SC) consists of Markus Graswald (Germany), Frikkie Mostert (South Africa), Sebastian Wurster (Germany), and Mickael Zeidler (France). I am happy to announce that Pengwan Chen (China), Thomas A Mason (USA), and Shannon Ryan (Australia) have joined our committee and will support our work in future.

The response to the Student Award call for Bruges was outstanding. We received 18 high-quality applications by students from Belgium, China, France, Germany, India, and the UK marking an all-time record high. So, it really provided a lot of work to committee members intensely evaluating all applications and making hard decisions at the end.



*Jack Riegel Student Award winners at the 33<sup>rd</sup> ISB*

The five winners at 33<sup>rd</sup> ISB in 2023 were:

- IB: Enfa FU (China), Molecular Dynamics Simulation of Solvent Dynamics inside Nitrocellulose-based Propellants During Drying Process.
- EB: Bernd DUTSCHKE (France), Aerodynamic Characterization, Flight Analysis and Limit-Cycle Stability for Artillery Shells Fired with High Elevation.
- EM: Christopher LANGE (France), Impact Thresholds for the Reactions of Metals.

- TB: Nicola REBOUL (France), Study of the interaction between shaped charge jets and ERA flying plates.
- VB: Gabriela BONEVA (UK), The Effects of Grazing Ballistic Impacts on Combat Helicopters and Behind Helmet Blunt Trauma.

Congratulations again to all winners and all those who handed in their application – even if not successful this time! I like to thank all committee members for their paper judgments, Frederik Coghe and his organization team for their great support in many aspects, as well as Thelma Manning for reimbursing the student winners.

For 34<sup>th</sup> ISB in Jacksonville in May 2025 we look forward to many student applications. This will be your chance to publish your scientific work, attend the conference, meet & greet and discuss with ballistic experts from all over the world! Please look for our announcements by broadcast email and on our [website](https://www.ballistics.org).

You may also contact us for feedback and / or questions at [student@ballistics.org](mailto:student@ballistics.org).

So let us top the current application record!

Dr. Markus Graswald  
(Education Committee Chair)

## THE IBS ONLINE STORE

by Clive Woodley  
Chair of the Membership Committee

The Online Store is a resource that is unique to the IBS. It contains the papers published in the proceedings of all the ISB (international Symposium on Ballistics). Also, since the 27<sup>th</sup> ISB, copies of many presentations given by oral presenters are available – nowhere else is there such a

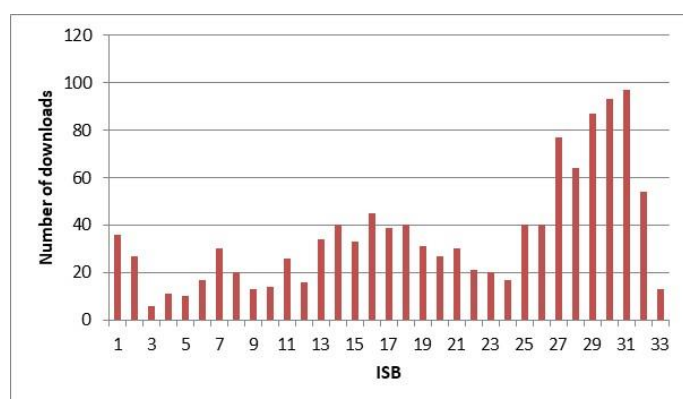
valuable resource. The IBS is sincerely grateful to those presenters who have agreed to make their presentations available to the IBS members (only).

All of the contents of the Online Store are available to members. Each term (approximately 18 months), most members can download free of charge a limited number of individual papers. Beyond that number, individual papers are charged at \$15. To non-IBS members, all papers are charged at \$20. All papers from the 1<sup>st</sup> and 2<sup>nd</sup> ISB are completely free of charge.

Presentations in the Online Store are all free, but are available to IBS members only.

Analysis of the papers downloaded indicate that some members make extensive use of this resource. However, it is possible that some members are insufficiently aware of the resource.

One of the purposes of this article is to make members more aware of this valuable and unique resource. The figure below shows the numbers of papers and presentations downloaded for each of the ISB.



Access to the Online Store is available from the Members Area Features ... Resources ...Online Store. After clicking the link, the member is taken to the resource which contains many links for each of the ISB. Scrolling down (note that the webpage can take several seconds to download all of the contents), the Member will see options by which the papers can be searched for key

phrases. Due to the limitations of the software used on the website (which is not in control of the IBS), the search facilities are somewhat primitive. However, the search options available work fairly well.

Another resource that will help identify suitable papers in the Online Store is an Excel spreadsheet which contains the paper titles, authors and abstracts from all of the papers. This file is at the location below.

<https://mms.ballistics.org/members/secure/filearchive/filelist.php?fac=3923>

The Online Store is updated after each ISB.

If you encounter any problems or have any questions concerning the Online Store then please contact Clive Woodley at [membership@ballistics.org](mailto:membership@ballistics.org).

If you have a resource which you would like to add to the Online Store then please contact Clive Woodley.



## LAB REVIEW

COUNCIL FOR SCIENTIFIC AND INDUSTRIAL  
RESEARCH (CSIR) SOUTH AFRICA

by David J. Reinecke  
CSIR, South Africa



South Africa's Council for Scientific and Industrial Research (CSIR) was established in 1945 as a statutory scientific research council and is the largest community and industry directed scientific and technological research, development and implementation organisation in Africa. With a total staff complement of more than 2 000 (scientists, engineers, technologists, technicians, sociologists and support staff) it is the largest of the South African science councils with a uniquely multidisciplinary skills base.

The CSIR dedicates its resources to improving the quality of life of South Africans through groundbreaking research, innovation, technology development and transfer. The organisation's mandate has remained the intrinsic guiding force over nearly eight decades, with the focus reviewed and renewed in response to changing global and local contexts and needs.

*"The objects of the CSIR are, through directed and particularly multidisciplinary research and technological innovation, to foster, in the national interest and in fields which in its opinion should receive preference, industrial and scientific development, either by itself or in co-operation with principals from the private or public sectors, and thereby to contribute to the improvement of the quality of life of the people of the Republic, and to perform any other functions that may be assigned to the CSIR by or under this Act." (Scientific Research Council Act, 1988 (Act 46 of 1988) as amended by Act 27 of 2014).*

From its inception, the CSIR's focus was on research that would typically not be undertaken by industry, starting with laboratories covering physics, chemistry, and building research, later adding two national institutes focusing on telecommunications and personnel research (industrial psychology), as well as industrial research institutes for the leather, fishing, paint, and sugar milling industries. Several other sector-directed centres and projects followed as did more and more technology transfer efforts including a growing patent portfolio and commercial ventures.

The organisation derives business value in having healthy strategic partnerships and stakeholder relations, locally and internationally, that enable and complement its capabilities to enhance and realise its vision of accelerating socioeconomic prosperity in South Africa through leading innovation and technology transfer. With its partners, the CSIR remains in pursuit of quality outputs and real impact.

Over the years, regardless of strategic shifts, the CSIR remained recognised for scientific excellence; innovation and quality; skills development; leadership in science; working through partnerships; ensuring transformation and making a difference through science to build a better South Africa.

## QUICK FACTS

- The CSIR is funded through a combination of baseline and ring-fenced grants from the Department of Science and Innovation, and contract research and development (R&D) income from the public and private sectors, locally, in Africa and internationally.
- Total turnover is in the order of R2.9 billion.
- The total staff complement is just over 2 000 of which 1 550 form part of the science, engineering and technology base.
- The CSIR head office is based on a 168 hectares site named *Scientia* in Pretoria, the capital of South Africa, located in the Gauteng Province.
- Smaller satellite sites operate from Johannesburg, Durban (KwaZulu-Natal), plus Cape Town and Stellenbosch in the Western Cape.

## ORGANISATIONAL RESEARCH FOCUS AND IMPACT

The CSIR continues to fulfil an increasingly important role in support of sustainable socio-economic development in South Africa through making science and technology of the highest quality available to markets and society. Work is undertaken in eight clusters aligned to high-impact sectors of the economy, namely:

### Industry Advancement Clusters

**CSIR Advanced Agriculture and Food** - Harnessing and applying the opportunities afforded by transformative technologies to develop the agriculture and associated processing industries for inclusive growth and rural development, while improving the industry's competitiveness through RD&I and business innovation.

**CSIR Future Production: Chemicals** –The cluster's customised approach to scientific research and development contributes to a sustainable, vibrant and competitive (South) African chemical and pharmaceutical industry.

**CSIR Future Production: Manufacturing** – Focussing science, engineering and technology base to contribute towards South Africa's re-industrialisation through developing or facilitating the uptake of new technologies that will improve the competitiveness and productivity of strategic local economic sectors. This includes localising and developing transformative manufacturing of existing and new products.

**CSIR Future Production: Mining** – Mirroring the long cutting-edge mining history in South Africa, the CSIR partners with industry in supporting the revitalization of the growth of this industry, contributing to the longevity of South African mining operations and assisting in the development and manufacture of South African mining equipment for local and export users.

**CSIR Defence and Security** – As a strategic and independent contributor to South Africa's sovereignty and the security of state and citizens, undertakes research and development to support South African National Defence Force readiness and operations and to support the competitiveness of local industry. As part of the South African Defence, Evaluation and Research Institute, focussing on strategic technologies and capabilities for air, land, sea and cyber defence security, strengthened



through selected international military research participation and collaboration, provides informed advice, engineering and certification testing along with tailored integrated solutions for private, public and civil sectors.

**Industry and Society Enabling Clusters**

**CSIR NextGen Enterprises and Institutions** –Incorporating digitally enabled technologies, contribute to improving operational efficiencies within organisations. Applies capabilities in disruptive technologies, such as artificial intelligence, the Internet of Things, digitalisation, modelling and simulation, and distributed ledger technologies for enhanced effectiveness, competitiveness, productivity and sustainability.

**CSIR Smart Mobility** –Addresses challenges and opportunities associated with transport systems and operations, infrastructure, transport operations and logistics management in support of industrial and sustainable development.

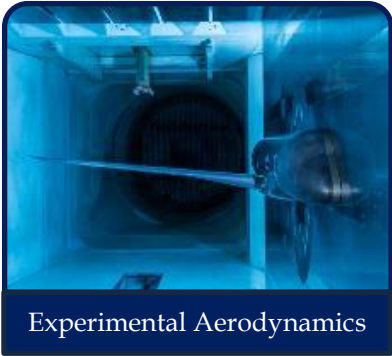
**CSIR Smart Places** – Uses multidisciplinary science, engineering and technology base in climate change, environmental sciences, energy, water, building science, spatial planning and cleaner production to contribute to smarter places, including smart buildings, cities and regions, manufacturing, water use and energy use.

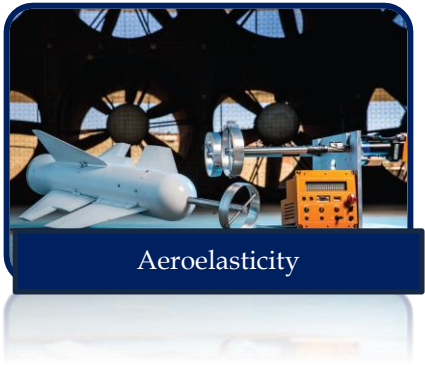
**THE DEFENCE ARENA**

The CSIR was established in the wake of World War II with initial core focus on radar and electronic warfare technology, a capability that still resides within the Defences and Security Cluster of the CSIR almost 80 years later. The CSIR operates within a unique DERI model where various disparate by military research focused organisations work together to provide strategic miliary technology-based knowledge, research, laboratories and solutions. The CSIR Defence and Security cluster is made up of seven units.

**Aeronautic systems**

Aerodynamic analysis, test and evaluation technologies; developing new tools, processes and technologies to deliver validated, cost-effective services;

<div><p>Aeronautic Systems Impact Area, Suite of Wind Tunnel Facilities</p><p>Experimental Aerodynamics</p></div>	<div><p>Characterising airframes using computational fluid dynamics, flight testing and wind tunnel testing:</p><ul style="list-style-type: none"><li>• Medium Speed Wind Tunnel (largest wind tunnel complex in the Southern Hemisphere, continuous, closed-circuit, variable density, captive trajectory system, Mach 0.2 to 1.4)</li><li>• High Speed Wind Tunnel (trisonic, blow down, Mach 0.6 to 4.3)</li><li>• Low Speed Wind Tunnel (continuous, atmospheric, closed-circuit, Mach 0 to 0.33)</li><li>• 7 metre Wind Tunnel (continuous, Eiffel wind tunnel, 2 to 32m/s)</li><li>• 2 metre Wind Tunnel</li><li>• Calibration Wind Tunnel</li></ul></div>
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	<ul style="list-style-type: none"><li>• Water Tunnel</li></ul>
<p>Aeronautic Systems Impact Area, Aeroelasticity, Ground Vibration Testing and Flutter</p>  <p>Aeroelasticity</p>	<p>Aeroelasticity capabilities include:</p> <ul style="list-style-type: none"><li>• Ground Vibration Testing and modal analysis</li><li>• Finite element modelling</li><li>• Unsteady aerodynamic analysis</li><li>• Flutter analysis</li><li>• Flutter excitation systems to support flight testing</li></ul>

**Radar and Electronic Warfare**

Recognised by international clients as a leading technology development, evaluation, application and training player in specialised radar and electronic warfare facilities, systems and hardware-in-the-loop solutions. Also undertakes radar capability establishment in other countries.

**Optronic Sensor Systems**

The CSIR’s research in the field of Optronic Sensor Systems (OSS) focuses on the development of new and novel electro-optic sensors/imagers and image processing techniques, through the modelling, simulation, engineering, testing and evaluation of advanced electro optical sensor systems for day, night and multispectral surveillance. In addition, researchers evaluate and design counter-measures for electronic warfare in the visual and infrared wavelengths. The OSS technology demonstrators and prototypes are designed to provide decision support for operational missions in various application domains including, at sea, land, air and space.

Aircraft Self Protection: Test and Evaluation; Measurement; Modelling and Simulation; Missile exploitation; Infrared counter measures; Directed Infrared Counter measures (DIRCM) jam code development

Advanced Optical Surveillance Systems: Forest fire detection camera for space and terrestrial applications; long range border safeguarding camera; wide area surveillance systems using real-time photogrammetry stitching;

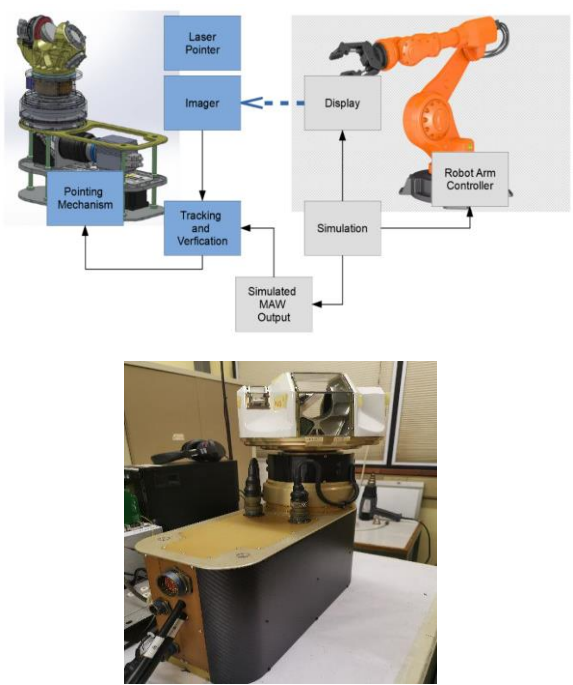
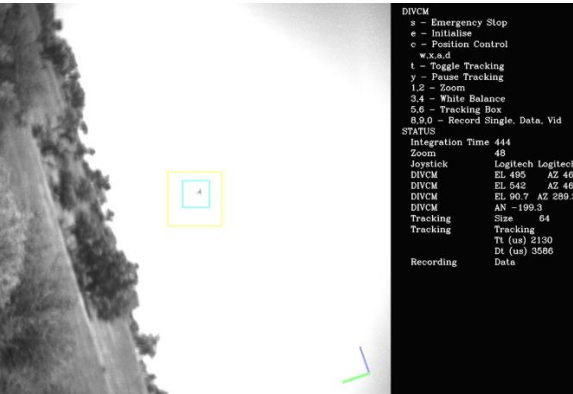
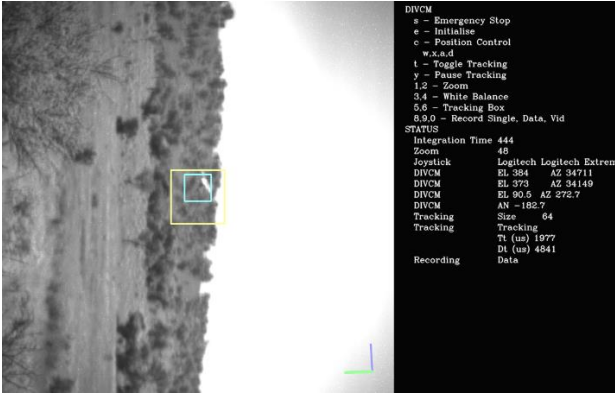
Surveillance Applications: Advanced CCTV image processing solutions for physical security applications using cutting edge deep learning neural networks; Forest fire disaster management; Land border safeguarding; Small target detection, recognition and tracking; vehicle based situational awareness systems

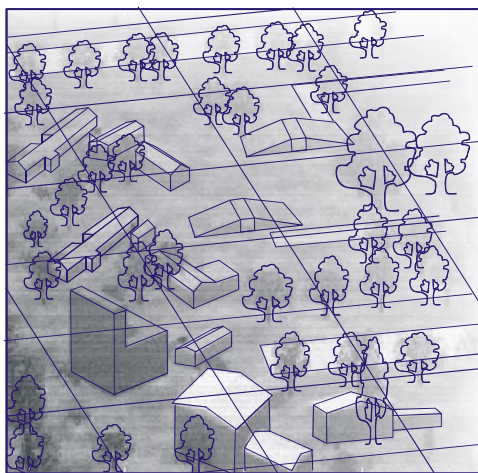
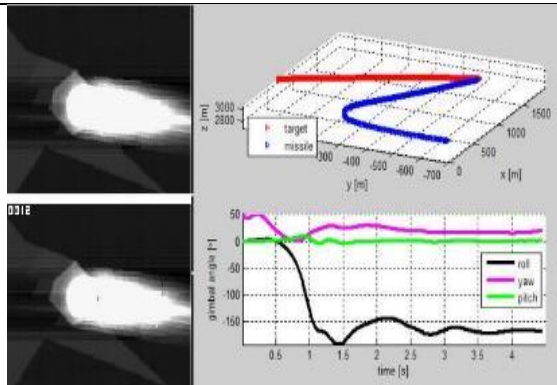
Information Applications: Automatic extraction of relevant information from videos and images for decision support; Satellite optical Radiometric Calibration and Validation (CalVal); Management



of large amounts of image data; Interface data streams to other sensor nodes; Exploitation/ utilisation of satellite image data.

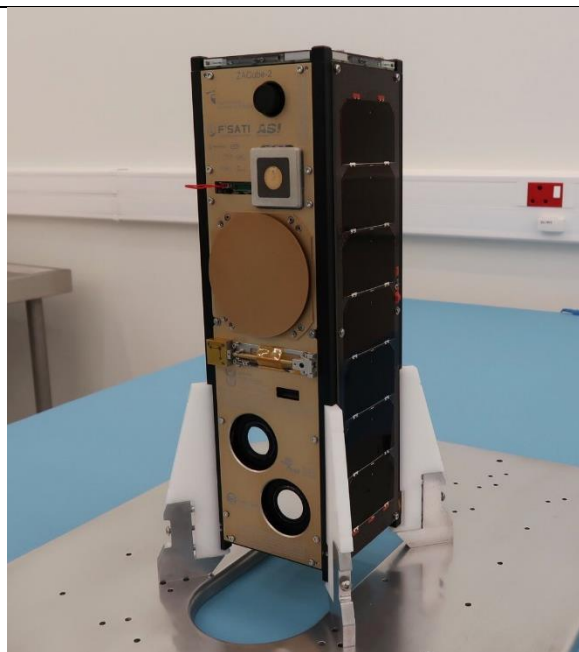
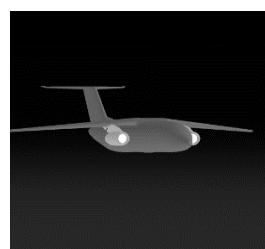
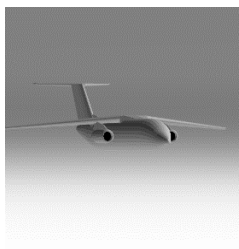
The research is supported by specialist facilities such as a test and evaluation laboratory, flight motion simulator, ship motion simulator and missile exploitation laboratories.

Optronic Sensor Systems	Capabilities
<div></div>	<p><b>Target Detection and Tracking</b></p> <p>The CSIR has a strong capability in real-time image processing that has been extended to develop applications for target detection and tracking. Computer Graphics Processing Units (GPUs) are used to accelerate image segmentation, object detection and target tracking.</p> <p>The tracking software is integrated with hardware platforms such as the Directed Optical Countermeasure (DOCM) platform to form a fast, precise and accurate pointing system for tracking small-fast-maneuvering targets. DOCM is a configurable system which can be integrated with various lasers and long-range cameras for experimentation purposes towards the development of DIRCM.</p> <p>DOCM can be integrated on land and naval platforms for detecting and tracking air targets such as drones, in cooperation with an early warning system such as a radar system for target designation.</p>
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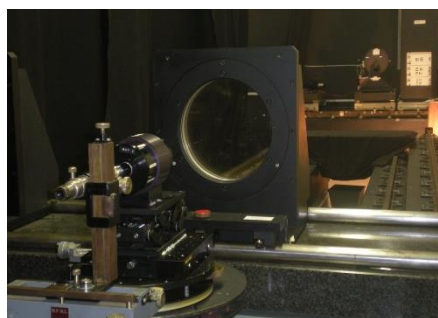
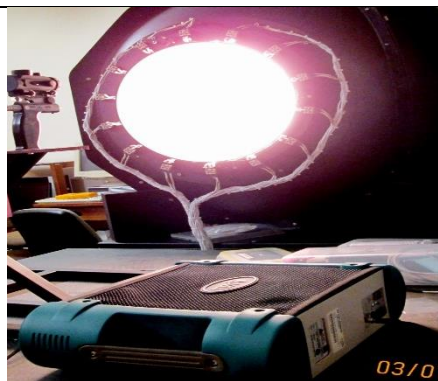
### Optronic Scene Simulator (OSSIM)

The development of sophisticated electro-optical equipment, such as infrared missile seekers and thermal imagers, requires radiometrically calibrated imaging scene simulators in order to evaluate and optimise system performance under diverse environmental conditions. OSSIM is an engineering development tool developed to meet this need. The simulator is written in C++ and runs on Windows and Linux systems. Accurate atmospheric modelling in OSSIM requires that MODTRAN be present. Current applications are mainly in the defence domain, but OSSIM can also be applied in the civilian world.



### Cubesat for forest fire detection

The CSIR developed a camera for forest fire detection from space. It was successfully integrated a camera into ZA-CUBE-2 as a secondary mission, with the main aim of testing and evaluating the camera in space for its ability to detect forest fires from 600km low earth orbit (LEO). The ZA-CUBE-2 satellite was successfully launched on 27 December 2018, and is currently operational. Imagery evidence has been received that shows that the K-line camera has survived the launch, the trip to space and is indeed capable of imaging the earth's surface. The technology is currently under-going performance verification and validation.



### The Test and Evaluation Laboratory

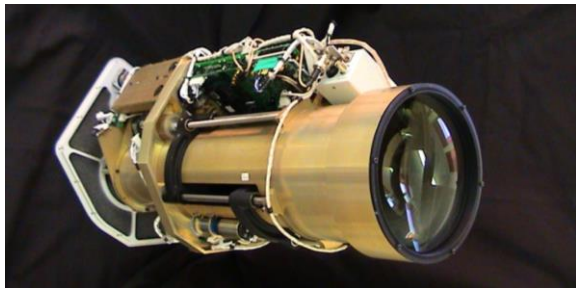
The situational awareness and threat identification afforded with surveillance cameras, night vision devices and infrared cameras, depend on the quality of images produced by these sensors. Performance deterioration occurs during normal use, storage or from abuse. This laboratory's capabilities include testing and evaluation of image quality on new and used sensors, in the field or in the laboratory. A range of real or simulated lighting and environmental conditions are possible. For clients, such test results provide confidence in continued tactical suitability of the sensor, or empower smart, informed acquisition or maintenance decision-making.



### WASS360

The Wide Area Surveillance System (WASS) provides instantaneous wide area situational awareness. With a panorama of 360° and a high-resolution digital video encompassing 4 000 x 1 000 at 20 frames per second, the sensor initially began operations in the visual band. The system evolved into a ruggedised module that was tested in the maritime domain for the detection of small craft, in support of anti-piracy operations. The WASS was further upgraded to employ thermal cameras and active cooling. Calibration of the cameras was done using the CSIR's patented Automatic Photogrammetric Camera Calibration System.



**CYCLONE**

CYCLONE in Meerkat 1 system



OTUS in MeerKat 2 system

**Long range border safeguarding camera**

The optical detection and tracking of targets at long ranges 5km to 20km, using cost effective solutions, is a challenging problem. Over the years, the CSIR has developed an impressive portfolio of solutions for long range imaging including CYCLONE, which was successfully integrated into the Meerkat 1 system, and demonstrated and deployed in an operational environment. The CYCLONE camera was eventually replaced by OTUS cameras which is currently integrated into Meerkat 2. A latest version long range camera RINO is currently being finalised, which will boast improvements in size, weight, and power consumption (Swap) and lower cost of production. In parallel to RINO, the CSIR is also developing a radar independent lightweight border surveillance camera, namely TYTO. TYTO will make use of a wide view IR channel for target detection, and a narrow field-of-view near infrared (NIR) channel for day and night operations.

**Landward Sciences**

Covers areas of tailored research and solution include soldier systems, firepower (including detonics), military mobility, vehicle and crew survivability. Military mobility research includes off road

military autonomous ground vehicle technologies including modelling and simulation and full-sized wheeled platform. Protection research capabilities supported by verified and validated computational modelling supported by high strain rate material testing. Test capabilities include an extensive Detonics, Ballistics and Explosives Laboratory for blast and ballistic testing. This laboratory has a variety of standard and unique detonic and blast impact and response test equipment and test facilities and capability to cast and assembly of conventional munitions surrogate as well as Improvised Explosive Devices for research, development, assessment testing. The area is able to execute compliant NATO AEP landmine and IED test panel and full vehicle protection assessment testing.

#### Detonics, Ballistics and Explosives Laboratory



#### Capabilities include:

- Onsite explosive casting / assembly / preparation facility
- Test NEC 50 kg above ground and 25 kg buried
- Range of standard and proprietary test capabilities
- NATO compliant AEP- Vol 2 and 3 testing

### Technology for Special Operations

Providing science, engineering and technology expertise for military capability in special operations, as well as the police and other security organisations. Includes advanced design, additive manufacturing, custom product development or adaptation.


### Underwater Explosives Research Facility

The CSIR's Defence and Security Cluster conducts underwater explosives (UNDEX) research at a test facility, in order to better understand underwater explosion phenomena. Knowledge gained from these experiments is applied in test and evaluation projects, or in training programmes offered by the CSIR. The small scale UNDEX facility consists of a 30 000 litre reinforced steel tank supported by a concrete slab. An overhead gantry is used for lifting test pieces and equipment into the tank. The tank is designed to withstand small-scale explosions of up to 30 grams of high explosive.

High-speed photography is used to capture explosive events by using photographic equipment that can capture up to 1 million frames per second, allowing researchers to follow the sequence of events, otherwise completely invisible to the human eye. Upgrades to its data acquisition system and sensor capability, has enhance the site capability.

### Command, Control and Integrated Systems

Focusing on security challenges of significant scope, with multiple contributors and shareholders, across the boundaries of function or organisation. Providing decision support, sustainable capability development and multiplatform, innovative solutions that address public or private sector safety and security challenges.

<p>Command Control and Integrated Systems</p> 	<p>Capabilities include:</p> <ul style="list-style-type: none"> <li>• Command &amp; Control</li> <li>• Operations – planning, tasking &amp; monitoring</li> <li>• Real-time situation awareness</li> <li>• Resource &amp; asset tracking</li> <li>• Incident management</li> <li>• Border safeguarding</li> <li>• Infrastructure protection</li> <li>• Interdepartmental operations</li> <li>• Government initiatives support</li> <li>• Military exercises and experiments</li> <li>• Transport and logistics</li> <li>• Asset tracking</li> </ul>
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### Information and Cybersecurity Centre

Supporting the private and public sectors: Specialist areas include identity management, cyber and information security solutions and approaches to securely identify and protect people (cradle to grave) as well as systems (physical and digital) against vulnerabilities, threats and risks.

### CONCLUSION

In closing, many decades of R&D and technology development puts the CSIR in a position to offer the defence client access to significant expertise – complemented by test, evaluation and measurement infrastructure and facilities of which many are unique in the world.

The group comprises R&D engineers (electronic, civil, mechanical, plus operations researchers and enterprise architects) and scientists in fields such as ballistics, computational modelling, optronics, radar and chemistry.

Operational insight and techno-military capability is complemented with expertise in other departments within the CSIR such as materials, health, manufacturing, computation, robotics, nano-technology, smart space design and environmental management.

CSIR Defence and Security brochure at:

<https://www.csir.co.za/csir-defence-and-security-brochure-0>





## SAFE OPERATION OF LIGHT-GAS GUNS WITH HYDROGEN: THE CASE STUDY OF THE “LARGE GUN” AT FRAUNHOFER EMI

by Stefano Signetti, Arno Klomfass, Werner Riedel, Robin Putzar, Andreas Heine.  
Fraunhofer EMI, Freiburg, Germany

### INTRODUCTION

There is growing interest towards the operation of two-stage light-gas guns with hydrogen to achieve higher projectile velocities. Inevitably, safety concerns have to be addressed. This is also motivated by the catastrophic event that occurred in 2012 at the light-gas gun facility of The University of Texas at Austin (UT) [1], [2], see Figure 1.

Safety has recently been reviewed also for the accelerators of Fraunhofer EMI [3], in particular for the “Large Gun” located in the basement of the EMI office building in Freiburg (Figure 2). This gun can accelerate masses of few hundreds of grams to hypervelocity employing up to 69 g of hydrogen for the complete filling, which is potentially enough to cause a detonation [4].



Figure 1: Video-news [2] of the accident at the UT light-gas gun in Leander on 12 June 2012. The damage to the metal-sheet housing resulted from both overpressure and accelerated gun components. A passing driver suffered minor injury.

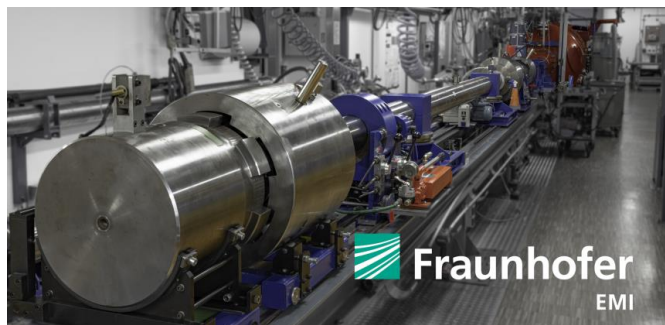


Figure 2: The Fraunhofer EMI “Large Gun”.

### ACQUISITION OF BACKGROUND INFORMATION

The knowledge of the *de facto* situation of the facility is fundamental to accurately define both initial and boundary conditions for the modeling and analysis processes. These include:

- H<sub>2</sub> leakage scenarios, given the specific gun characteristics and operation procedures;
- Non-structural components with limited overpressure resistance, e.g., separating walls, doors, windows, the failure of which may result in the blast propagation outside the lab and, therefore, the identification of those surrounding areas affected thereafter;
- Structural characteristics of the affected locations, including building construction details and acting structural and non-structural preloads;
- Presence of people within the areas potentially affected by the blast propagation or structural damage.

This has required an extensive analysis of various documentation, which starts from 1959, when the EMI building was first erected, including multiple renovations and extensions in the following decades.

### IDENTIFICATION OF THE CRITICAL SCENARIOS

By analyzing the possible failure mechanisms of the Large Gun components at different stages of operation together with turbulent flow simulations [5], the following leakage scenarios

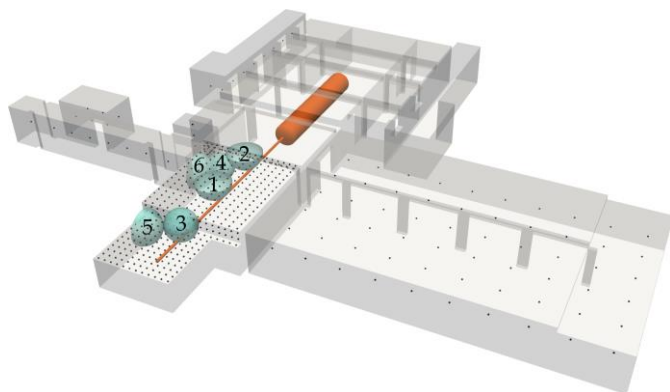


Figure 3: Location and size (to scale) of the simulated H<sub>2</sub>-air-mixture clouds for the six defined deflagration scenarios. The black dots identify the gauge points used in the CFD analysis for the computation of the overpressure time history.

are identified:

1. Loosening of the piston at the rear of the pump tube connected to the powder chamber;
2. Hydrogen leaks radially from an opening along the pump tube;
3. Hydrogen leakages from the high-pressure section split towards four radial directions with a 90° step.

All leakage scenarios result in one or more hydrogen jets propagating away from the gun. Their exact direction depends on how the components specifically fail, which is impossible to predict. Therefore, the leakage scenarios are deliberately kept imprecise with respect to the location along the gun and jet directions. Instead, the laboratory is screened to identify locations where the ignition of the resulting H<sub>2</sub>-air-mixture clouds would cause the most significant damage to both critical structural and non-structural components.

Although a sensor-triggered mechanism is implemented to stop the filling of the gun, the combustion of all 69 g of hydrogen is conservatively considered. This results in about 2.8 m<sup>3</sup> of stoichiometric H<sub>2</sub>-air mixture at the given environmental conditions. According to turbulent flow simulations [5], the flame velocity would never

exceed about 120 m/s. Thereby, the corresponding combustion is always subsonic.

Overall, six deflagration scenarios are then determined (Figure 3).

## CFD ANALYSIS

As a first step, the overpressures are computed with the CFD code *APOLLO Blastsimulator* [8], developed by Fraunhofer EMI. Relevant regions of the modelled domain are sampled with gauge points (Figure 3). The resulting time-history curves are used in direct safety assessment by comparison to critical values [9] as well as an input for explicit dynamics analysis on structural components of the building.

A CAD geometry of the surfaces enclosing the areas of interest (Figure 3) is used to define a set of rigid-wall boundaries. Where the flux needs to extend beyond the computational domain, e.g., to account for the propagation towards external areas or upper stories of the building via the elevator core, non-reflecting boundaries at ambient state conditions are used.

The failure of non-structural elements (i.e., doors, windows) is modeled by instantaneous removal of the corresponding parts of the voxel model. This is triggered when the transient average net overpressure acting on the corresponding surface exceeds a set threshold, which is determined upon available information such as the technical specifications by the manufacturer.

Some typical outputs of the CFD analysis are depicted in Figure 4 and Figure 5, in terms of peak overpressure values over the whole spatial/time domains and complete time history at selected locations, respectively.

The performed blast simulations cover a time span of 100 ms. The whole H<sub>2</sub> mass is already combusted within about 15 ms after the ignition.

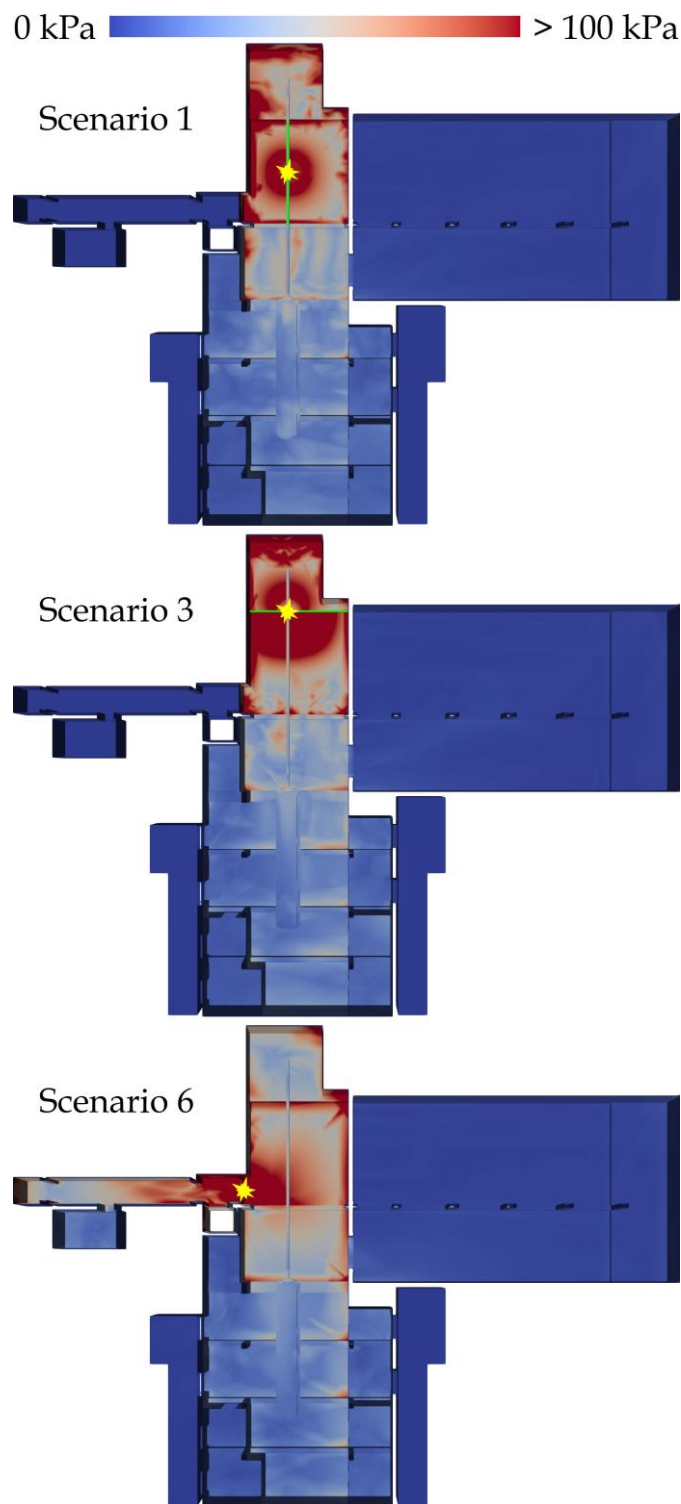


Figure 4: Contour of the maximum overpressure in the analyzed domain for selected deflagration scenarios, cf. Figure 3: leakage along the pump tube (top); leakage at the powder chamber (middle); leakage at the high-pressure section (bottom). For the latter, the blast propagates to the entrance corridor upon failure of the laboratory door. The corresponding ignition points are highlighted.

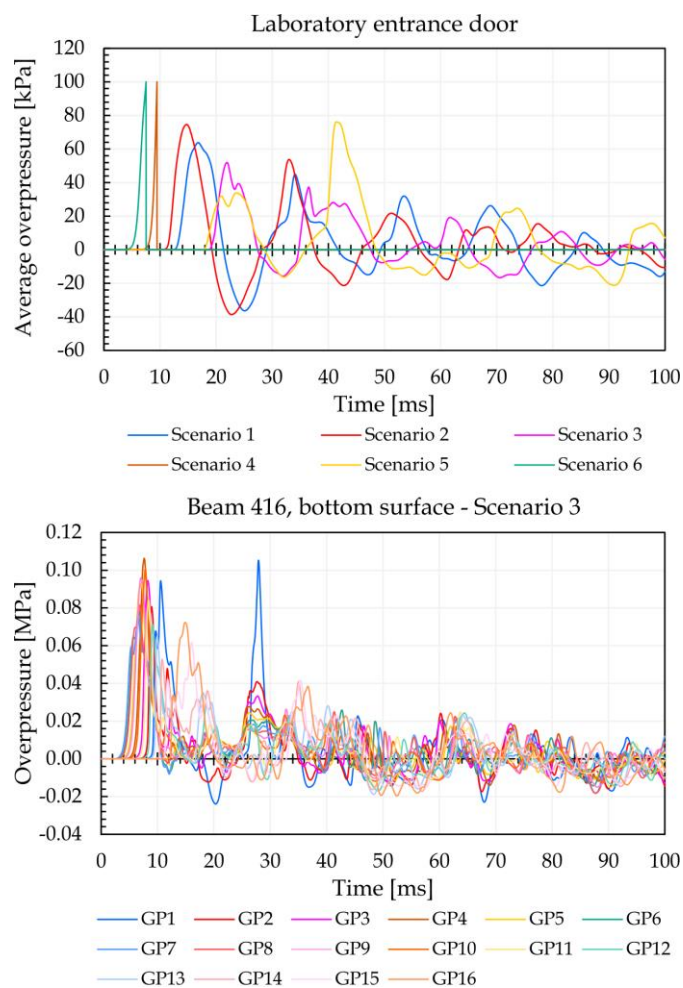


Figure 5: Time-history output of the CFD analysis. Top: net overpressure on the entrance door; for scenarios 4 and 6 with nearby deflagration, cf. Figure 3, the acting force drops when the set threshold is exceeded allowing propagation to the corridor, cf. bottom panel of Figure 4. Bottom: overpressure at selected gauge points (GP) mapping the surface of the beam highlighted in green in Figure 4 under Scenario 3; these curves are then applied as dynamic load in structural simulations.

## STRUCTURAL DYNAMICS ANALYSIS

The load-bearing reinforced concrete elements closest to the leakage locations are then analyzed via explicit dynamics simulation in LS-DYNA. Beams and columns are modeled with a combination of solid elements (concrete) and beams (steel rebars), reproducing with high detail the constructive characteristics according to the structural documentation (Figure 6).



Structural elements in the FEM model are subjected to static preloads in their most critical combination. These are applied via the explicit dynamic relaxation technique in order to approach the static equilibrium and prevent dynamic effects before the transient analysis is performed. The structural elements are modeled as singular entities, yet accounting for the actual constraints from the other elements connected to them. Depending on the structural typology, e.g., for a steel structure like the UT laboratory, or the level of induced actions, a global analysis of the whole building, also considering instability issues, may be required at later stages.

The EMI-developed Riedel-Hiermaier-Thoma (RHT) material model [10] is used to describe the concrete constitutive and failure behavior. The Johnson-Cook material model [11] is adopted for the rebars; thermal dependence is neglected.

For the assessment of the structural integrity, the output analysis focuses on monitoring:

- The displacement at selected gauge points (typically – but not necessarily – overlapping to those of the CFD model) to indirectly assess the structural integrity;
- The RHT damage function,  $0 \leq D \leq 1$  [10], to evaluate the direct and load-induced damage in concrete;
- Possible plastic deformation in the rebars.

Figure 6 shows a typical result of the FEM analysis. After the deflagration, cf. Scenario 1 in Figure 3 and Figure 4, the beam of the laboratory ceiling just above the pump tube shows a permanent deformation, vibrating around a midspan deflection of 0.94 mm with respect to a value of 0.44 mm at  $t = 0$  ms resulting from the static preloads. This originates entirely from the damage in the concrete, localized at supports and along the beam, since no plastic deformation occurs in the rebars. Although the ceiling is not expected to collapse, secondary effects at the first floor of the building, such as furniture falling over or damage to the masonry walls,

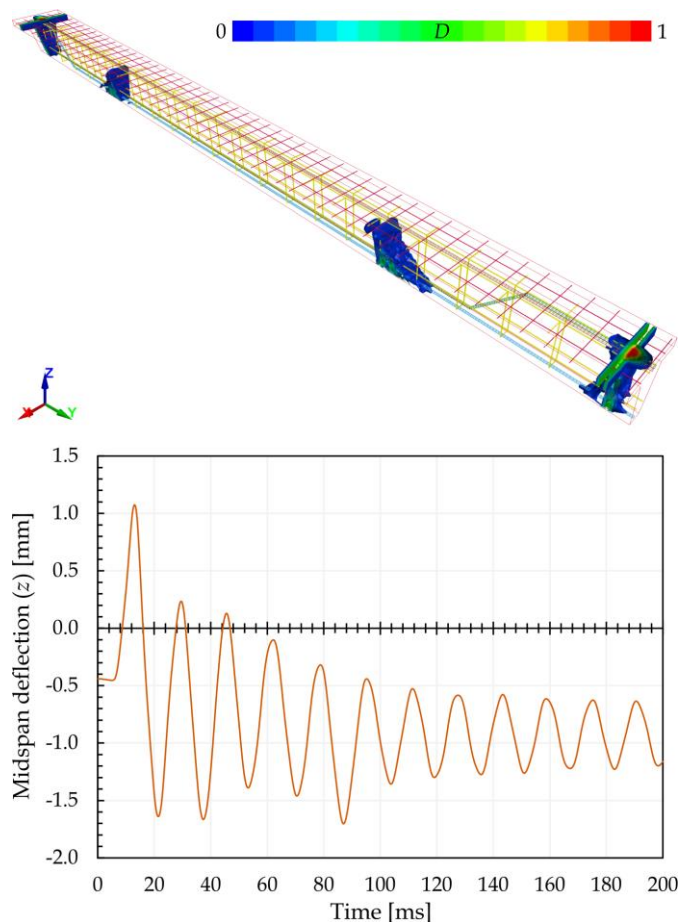


Figure 6: Exemplary results of the explicit dynamics simulation for the ceiling of the laboratory under Scenario 1, cf. Figure 3 and the beam highlighted in green in Figure 4 for the corresponding scenario. Top: contour plot of the RHT damage function; the image also shows details of the steel reinforcement in the FEM model. Bottom: blast-induced vertical displacement at the midspan of the beam.

cannot be excluded due to a computed peak total displacement of about 2.6 mm. In such a case, a preventive non-destructive strengthening of the beam [12] may represent a viable and relatively economic solution.

The other structural elements considered in the analysis, either beams and columns, are much less affected by the deflagration since they are relatively massive if compared to the ceiling. For these, only minor damage in concrete is observed and instability phenomena can be excluded.

## A SIMULATION-SUPPORTED OPERATION

The performed analysis provides a ground base for the discussion and design of possible safety countermeasures. These could include, for example, the reinforcement of structural components, the evacuation of further areas of the building during the operation of the light-gas gun with hydrogen, the permanent closure or strengthening of some doors and windows of the laboratory.

The effort of such full-scale computational analyses can be compensated by the resulting targeted and more effective interventions, also economically, which may reduce the temporary shutdown period of the facility for its retrofit or even prevent its relocation.

For the interested readers, extensive details of the analysis performed for the Large Gun laboratory of Fraunhofer EMI are available in Ref. [13].

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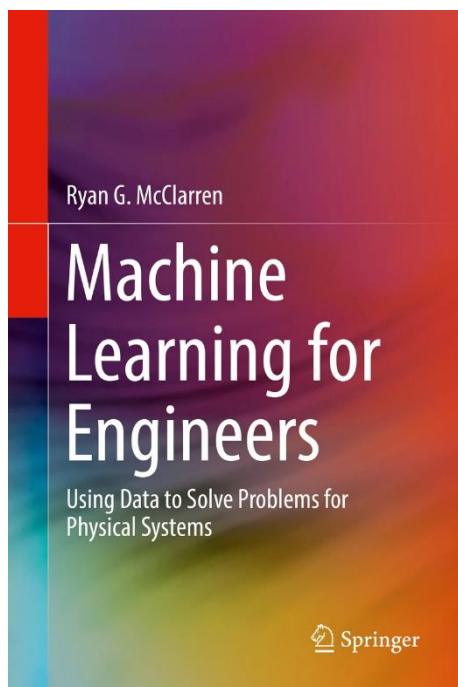
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## BOOK REVIEW

by A. Klavzar

French-German Research Institute of Saint-Louis, Germany

In this issue we present a book about the possible applications of machine learning methods for engineering problems.



**AUTHOR:** Ryan G. McClarren

**PUBLISHER:** Springer Cham

**PAGES:** 247

**FORMAT:** Hardcover, Softcover, eBook

**ISBN (Hardcover):** 978-3-030-70387-5

It is the first edition of a book published in 2021 by Prof. Ryan McClarren, Associate Professor of Aerospace and Mechanical Engineering at the University of Notre Dame. Amongst other positions Prof. McClarren was research scientist at the Los Alamos National Laboratory in the Computational Physics and Methods group.

As written in the preface is the aim to show engineering and science students how machine learning methods can be applied to their field of research, as his connection is often not seen. I can say as a rather experienced scientist in terminal ballistics with minor knowledge in machine learning methods during reading the book I found a lot examples which I considered to be applicable to our scientific discipline.

The book is separated in three main parts, Fundamentals, Neural Networks and Advanced topics plus appendices with implementation examples. Each chapter starts with an abstract and keywords, what makes it easy to scroll through the book searching for a certain problem. After each sub-chapter a summary is given.

The “Fundamentals” part of the book is divided in 4 sub-chapters:

- The general concepts of supervised and unsupervised learning.
- Linear models for regression and classification, which comes with the interesting examples of an object in free fall or how to determine governing equations from data.
- Decision trees and random forests for regression and classification with the (especially for me) interesting example how the result of a numerical simulation can be predicted. The example is the simulation of a laser driven shock launched into a beryllium disc.
- Finding structure within a data set – for sure helpful for anyone analyzing big data sets

In the second part (“Neural Networks”) the theory and applications of feed forward neural networks is developed and at the end explained with an application example. For the theoretical explanation for sure maths is needed, still, one can read the chapter without trying to comprehend all the formulas and will still understand at the end the basic concept.

The example at the end explains how neural networks can for example be used to predict the



strength of concrete as a function of age and ingredients from a data set with the help of a neural network.

In the “Advanced Topics” part different methods for certain problems are explained:

- Recurrent neural networks which are tailored to solve problems where the inputs are time series data. As an example, it is shown how the frequency and shift of an oscillating signal can be found.
- Long short-term memory networks, used in the example to determine the behavior of a cart mounted pendulum.
- Autoencoders used for example for data reduction from a physics simulation and finally reinforcement learning with policy gradients, applied to control the cooling of glass in an industrial process.

To summarize, all the applications and examples in the book are related to engineering problems, and I guess anyone working experimentally or with numerical simulation will find an example which can be related to his work.

Still, reading the book once gives only an overview on the possible applications and explains the general methods how the machine learning method works.

After each chapter references are given for those who want to dig deeper in a certain subject.

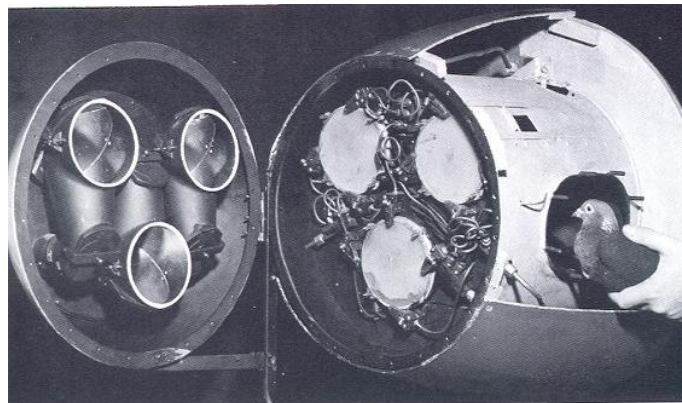
## DID YOU KNOW...?

...that the US military tried to use pigeons as missile guidance systems during and after WWII?

The idea was developed in 1940 by B.F. Skinner, a professor for psychology at the University of Minnesota. He argued that pigeons were reliable, intelligent, steadfast, and could not be

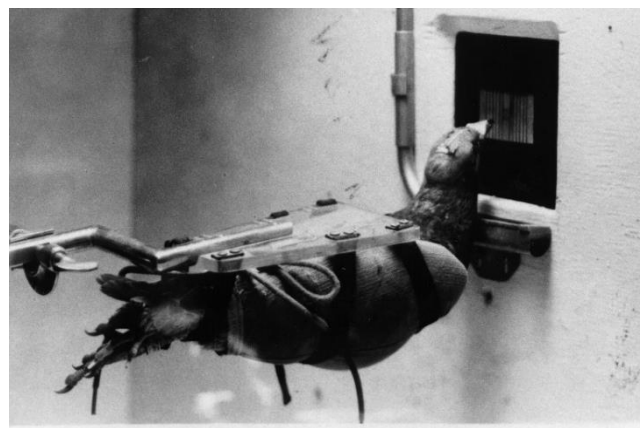
jammed by technological intervention by the enemy. These attributes would make them excellent missile guides.

Despite initial refusal, the Office of Scientific Research and Development gave General Mills Inc., which was funding Skinner at that point, a contract to try and develop his proposed pigeon guidance system.



*Nose cone of NIST glide bomb showing the three-pigeon guidance system. Credit: American Psychological Association*

The pigeons (they were found to work best in a trio) should be placed in the nose cone of a missile. Each pigeon should be looking at a small electronic screen displaying the ground ahead of the missile. As the pigeons would peck at the target, small pulleys attached to their heads should steer the missile.



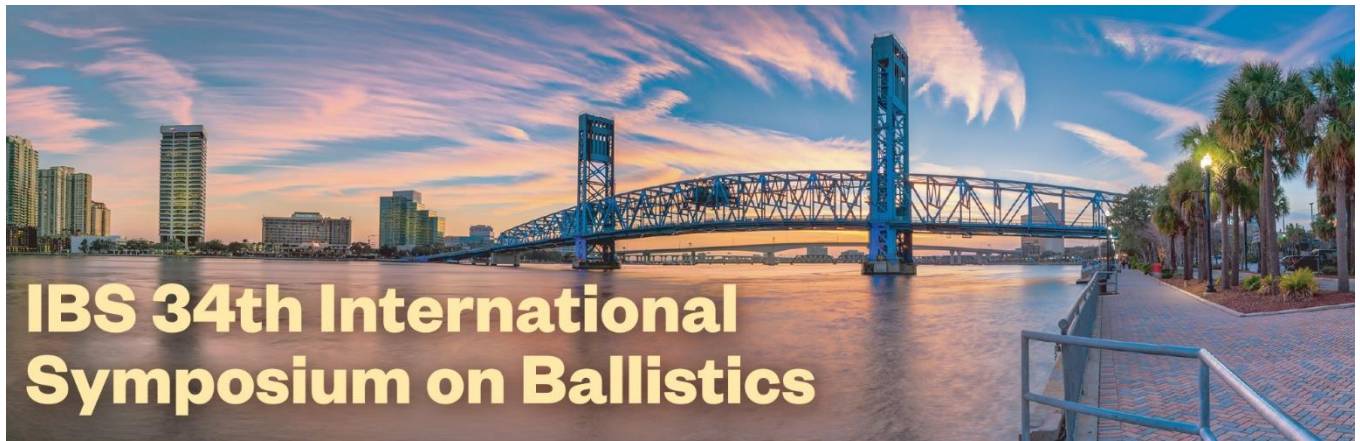
*Pigeon fixed to a frame in front of a screen  
(<https://www3.uca.edu/iqzoo/Media/Pics/pigeon2.jpg>)*

Experiments with the pigeons in separate compartments were remarkable successful. The pigeons were quite adept at identifying and homing in on targets and even noises, bright lights, temperature swings, altitude changes, or g-forces did not affect the animal pilots. Nevertheless, in 1944, the Army shut down Project Pigeon in favour of projects with “more immediate promise of combat application”.

But this was not the end of Skinner’s vision: in 1948, the program was revived by the Navy under the new name Project Orcon (acronym for “organic control”). The aim was now to develop pigeon-guided anti-ship missiles.

However, fortunately for the pigeons, the development of electronic guidance systems rapidly advanced and soon made Project Orcon obsolete. Eventually, the program was discontinued in 1953 without the pigeons having gotten off the ground.

Skinner kept the pigeons and even six years later they could still identify their targets. Nevertheless, Skinner himself later described the project as a “crackpot idea”...



**May 18–24, 2025 | Jacksonville, Florida, USA**

**The 34<sup>th</sup> International Symposium on Ballistics will be held from May 18 to 24, 2025 in Jacksonville, Florida, USA.**

The International Symposium on Ballistics (ISB) is known to be the prime international scientific event in the field of ballistics. Traditionally, the ISB features the most current state-of-the-art technology, provides opportunities for interactions with some of the world's leading experts in this field and offers the chance to present, exhibit and share scientific research and development with an international group of professionals.

The symposium covers all traditional areas of ballistics science:

- Exterior ballistics
- Interior ballistics
- Terminal ballistics
- Explosion and warhead mechanics
- Launch dynamics
- Vulnerability and survivability

but also welcomes papers and presentations on emerging technologies including hypersonics, AI, drones and other new technologies related to ballistics.

#### IMPORTANT DATES

The call for abstracts has already been released and abstracts will be accepted until October 11<sup>th</sup>.

The deadline for the submission of the Defence Technology (DT) Special Issue full papers will be November 10<sup>th</sup>, 2024.

Detailed information on the abstract submission can be found on ISB website (<https://mms.ballistics.org/members/proposals/propselect.php?orgcode=IBSO&prid=1428197>).



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#### VENUE

The symposium venue will be the HYATT REGENCY JACKSONVILLE RIVERFRONT, in



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The room link with the ISB rates will be available soon. For detailed information on the Hyatt Regency Jacksonville Riverfront, please visit the hotel website <https://www.hyatt.com/hyatt-regency/jaxrj-hyatt-regency-jacksonville-riverfront>



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## OTHER UPCOMING EVENTS

# 19TH ISIEMS

**19th International Symposium on the Interaction of the Effects of Munitions with Structures**

What? International conference on “Weapon Effects on Structures”

When? December 9 to December 13, 2024

Where? Bonn, Germany

Link: <https://www.bundeswehr.de/en/organization/infrastructure-environmental-protection-and-services/isiems/19th-isiems>

**24th Biennial Conference of the APS Topical Group on Compression of Condensed Matter (SCCM2025)**

What? International meeting on static, dynamic and shock compression and detonation physics research

When? June 22 to June 27, 2025

Where? Washington, DC

Link: <https://engage.aps.org/gccm/meetings/biennial-2025>

**27th International Symposium on Military aspects of Blast and Shock**

What? International symposium on military related blast and shock wave research and associated thermal effects

When? late September 2025

Where? Colmar, France

Link: <https://www.mabs.ch/next-mabs/>





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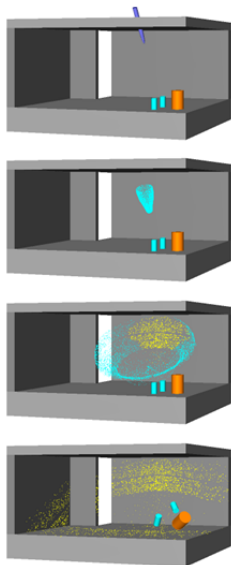
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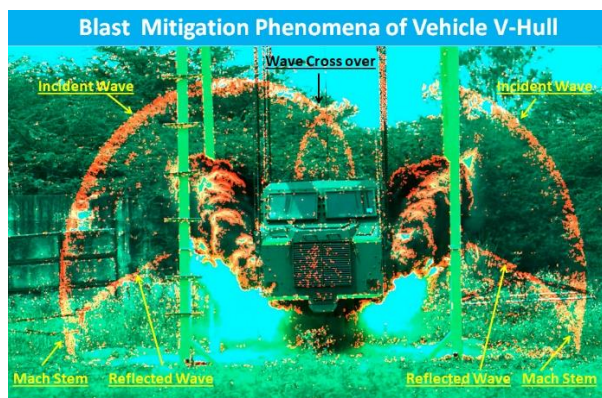
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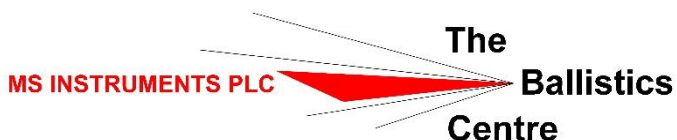
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