FFI RAPPORT

Minutes of the 2004 annual meeting of ANNC WGIII

DULLUM, Ove

FFI/RAPPORT-2004/03867

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8) ABSTRACT

This report contains the minutes of the annual meeting of the Anglo Netherlands Norwegian Cooperation Working Group III on Warheads (ANNC WGIII) held at FFI, Kjeller 23rd - 24th September 2004.

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2004-11-04	Bjarne Haugstad	Director of Research

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Minutes of the 2004 annual meeting of ANNC WGIII

1 INTRODUCTION

The annual meeting of the Anglo-Netherlands-Norwegian Cooperation Working Group III (Warheads) was held at Forsvarets Forskningsinstitutt (FFI), Kjeller, Norway, 22nd – 23rd September 2004.

The meeting was attended by 7 Dutch and 3 British delegates in addition to 5 Norwegian participants. The meeting was lead by Dr Bjarne Haugstad, the Norwegian national leader.

A list of attendees with their coordinates is shown in appendix A

The agenda for the meeting is shown in appendix B

2 MINUTES OF THE 2003 MEETING

The minutes of the 2003 meeting held at TNO-PML, Rijswijk, Netherland were accepted as a true and accurate record

3 REPORT ON THE 2003 PRINCIPALS MEETING

The ANNC Steering Comittee meeting was held on the HMS Belfast in London. Questions were raised whether ANNC should continue to exist as it currenly does, or whether it in some way should be subordinate to the Europa MOU. As WG III has close links to CEPA-14, some tasks could and will indeed take place within this framwork. However, as WG III remains very active and good participation exists, it should therefore be allowed to continue. It was noted that working groups like WG III operate within and across CEPAs and thus offer a valuable vehicle for cooperation complimentary to the Europa MOU.

4 UPDATE ON THE NATIONAL SITUATION

4.1 The Netherlands – TNO-PML

Maarten Manders presented the state of TNO-PML

There are some significant changes about to qccur at TNO. It was explained that TNO-PML will be combinded with TNO-FEL and TNO-TM to form TNO Defence, Security and Safety, as one of five core areas with the new TNO organization. The individual institutions will thus cease to exist. The institution of the new core areas will improve the ability of TNO to serve its markets. (see appendix F.1)

4.2 The United Kingdom – DSTL

Adam Cumming presented the state of Defence Science and Technology Lab.

The DSTL organisation will in near future be located at just three major sites in the UK: Portsdown West, Porton Down and Fort Halstead. Currently DSTL is located at nine sites. UK MOD has redefined its research strategy in a way that it will become output-driven ensuring that technology and advice get to the right people. (see appendix F 2)

4.3 Norway – FFI

Bjarne Haugstad gave an overview of the situation at FFI.

FFI has gone through a reorganisation, however the charter remains unaltered. The previous 3 divisions have now been organized into 5 divisions with names that more clearly reflect the activity. The divisions are: Analysis, Information Management, Land & Air Systems, Maritime Systems, and Protection. (see appendix F 3)

FFI remains the only defence research organisation in Norway.

5 REVIEW OF COLLABORATIVE ACTIVITIES

CPIII-5b Lifetime extension of propellants, explosives and pyrotechnics (UK, NL)
Final report is in the process of being written. Any programme meeting has not taken place during the previous year. A future meeting in Stockholm is planned. Any follow-up will preferably be done at a tri-lateral basis. An annual report has been issued. (see actions 2004-1 and 2004-2)

CPIII-10 Soldier modernization program (SMP) (UK, NL)
No formal meetings have taken place. The intention of this programme is in need of being clarified, otherwise the programme should be terminated. Programme plans should be produced by the end of 2004. (see action 2004-3)

CPIII-12 AFV mine protection (UK, NL)
A final report has been issued. The possibilities of a follow-up programme should be investigated. (see action 2004-4)

CPIII-13 MINEN model (UK, NL)
The planned meeting to be host by UK has not taken place. The Netherlands still has an interest to discuss the possibilities of a future collaboration, though the prospects for a future programme seems to be diminishing. The future of the programme has to be clarified very soon. An annual report has been issued. (see action 2004-5)

CPIII-14 Air Target Vulnerability (UK, NL)
Several meetings have taken place over the last year and 4 draft reports have been issued. A proposal for follow-up work still has be worked out (see actions 2003-4 and 2003-5).

CPIII-16 Penetration into Concrete – Phase 2 (NL, NO, UK)
There has been low activity over the last year. A report has been issued. Some degree of information exchange is taking place. (see action 2003-7). A decesion on future activity is due to be taken (see action 2004-6)

CPIII-17 Protective Structures
Information exchange and visits between UK and NL have taken place. Otherwise, the state of affairs is the same as for CPIII-16. A decesion on the future is pending. An annual report has been issued. (see action 2004-6)

CPIII-19 Optimisation of Exploding Foil Initiation of IM Explose Candidates (NL, UK)
Reports have been exchanged. The foils used have not been able to initiate any of the candidates due to limitations in impulse. Final report to be issued by the end of 2004. Two annual reports have been issued.

CPIII-20 Study of dwell phase phenomena of ceramics during impact (UK, NL)
The synopsis of the work has been presented for the International Symposium on Ballistics. A formal final report has yet to be issued (see action 2003-10). A proposal for a new activity has been issued. (see appendix E) Norway will also attend the project provided funding will be provided. An annual report has been issued. A programme for tri-lateral collaboration on projectile modelling will also be worked out. (see action 2004-9)

CPIII-21 Mitigation of blast and fragment hazard from from EOD operations (NL, UK, NO)
An elaborate test by TNO-PML has been done at Hjerkinn, Norway with the assistance of FFI. The tests involved 6 Mk82 multipurpose bombs. The results were presented by Howard Looder at the meeting. Final report is pending. No UK involvement so far. A decesion of the future of the ANNC programme should be made. An annual report has been issued. (see action 2004-11)

CPIII-22 Close Action Environment (CAEN) (NL, UK)
Programme is concluded. No basis for collaboration An annual report has been issued.

CPIII-23 IUSS (NL, NO)
There are diffuculties for Norway to get access to the software. Thus no basis for ANNC cooperative project. Program is terminated. An annual report has been issued.

CPIII-24 Aircraft vulnerability
Covered by CPIII-14. This CP was intended as a follow-up of that. Two annual reports have been issued. (see action 2003-6)

CPIII-25 Performance and IM Properties of New Explosives (UK, NL)
No activity. A programme for continuation should be work out. (see action 2002-12)

CPIII-26 Secondary flyers
Some activity including experimental setup and velocity measurements. A meeting to discuss further plans will be held. An annual report has been issued.

CPIII-27 Close Combat Modelling
Bilateral UK-NL collaboration is planned as a non-ANNC programme precluding Norwegian participation. The content is very substantial. The Norwegian interest in the topic is diminishing. Termination of ANNC programme is most probable. An annual report has been issued.

CPIII-28 Burster Slab Technology
Related to CPIII-21. A decesion on the continuation should be made. (see action 2004-11).

CPIII-29 Emerging technologies
The UK contribution were presented at the meeting.

6 ACTIONS ARISING FROM THIS AND PREVIOUS ANNUAL MEETINGS

A list of action was set up during the meeting as a result of a the review process. The following list contains all the original item with 5 additional actions encounters through a post-meeting review. Actions arising from 2003 or earlier being left out of the present list should be considered as completed, deleted or overtaken by other actions.

Names written with a bold font should indentfy the person having the main responsibility for the action.

No.	CPIII-	Issue	Time due	Responsible
2001-35		Provide information on Health Usage Monitoring System (HUMS)	12/04	Dave Tucker
2002-12	25	POC to rewrite programme to reflect current levels of interest	04/05	Richard Bouma Nat. leaders
2003-3	12	Consider a follow-up programme for AFV Mine Protection	12/04	Ton Verhoeven **Ian Pickup** Ove Dullum
2003-5	15	Write and release reports on CPIII-14 Air Target Vulnerability		**Pat Collins** Peter Doup
2003-6	15	Write a programme proposal for TOR for CPIII-24 Aircraft Vulnerability		Pat Collins Peter Doup

2003-7	16	Release annual and final report for Penetration into concrete	12/04	**Jim Sheridan** Jaap Weerheim
2003-8	19	Issue final report on CPIII-19	12/04	**Mark Wasko** Huub Keizers
2003-9	26	Discuss possible options for follow-up programme	12/04	**Huub Keizers** Mark Wasko
2003-10	20	Prepare an executive summary on dwell phenomena	10/04	**Ian Pickup**
2003-18		Prepare and agree on CP progress reports to nat. leaders		**All**
2003-20		Present national view on DEW		**UK** NO
2003-22		Explore potential for collaboration on human vulnerability	12/04	**Paul Dearden** Theo Verhagen
2003-23		Circulate to nat. leaders info. on human vulnerability related to safety distances in order to assess whether this item should be included	12/04	**Louk Absil**
2003-24		Explore the potential for cooperation on assessing occupant safety with MADYMO	12/04	**Paul Dearden** Ove Dullum (Piet-Jan Leerdam)
2003-25		Provide written reports on Boundary effects penetration mechanisms	03/05	**Jaap Weerheim** Jim Sheridan (Jan Arild Teland)
2004-1	5b	Issue final report	12/04	**Dave Tucker**
2004-2	5b	Assess possibilities for follow-op program	12/04	Dave Tucker Huub Keizers Tove Karsrud
2004-3	10	Clarify intention, or terminate, of Soldier Modernisation Programme	12/04	**Nat. leaders**
2004-4	13	Clarify the future of the MINEN programme	12/04	Adam Cumming
2004-5	16	Investigate the status of CPIII-16 with optional termination	12/04	Nat. leaders
2004-6	17	Investigate the status of CPIII-17 with optional termination	12/04	Nat. leaders
2004-7	19	Write final report on CPIII-19	12/04	Huub Keizers
2004-8	20	Distribute proposal on programme on Ceramic Armour	10/04	**Ian Pickup** M vd Voorde Ove Dullum
2004-9	20	Develop proposal on Projectile Modelling	01/05	**M**artin **v d Voorde** Ian Pickup Ove Dullum
2004-10		Develop proposal on lightweight armour protection	03/05	**Andre Diederen** Ian Pickup Ove Dullum
2004-11	21/28	Determine status of programmes and if appropriate take forward		Nat. leaders
2004-12		UK to identify interest in DEW	12/04	Adam Cumming
2004-13		Host discussion meeting DEW	03/05	Maarten Manders
2004-14		Discuss and develop activities on agreed	06/05	National Leaders

		topics for forthcoming year (Fuzing; Nanotechnology for Energetics; Electric Armour; Scaleable Munitions, MTV ageing, Poly-nitrogen performance)		
2004-15		Review paper on Scaleable Munitions	03/05	National Leaders

7 PRESENTATIONS

7.1 Ballistics analysis and modelling of ceramic armour subject to KE threat (Ian Pickup)

In his presentation Ian Pickup focused on the occurrence of dwell and the development of a system to assess dwell. There is a new programme involving DSTL-PML-FFI to develop a model for quantitative ballistic investigation, analytical/empirical model an the development of material models. (see appendix F 4)

7.2 Ceramic Protection (Martin van der Voorde)

Examples of finite element simulations (Autodyn) were shown of projectile-target interactions. Various projectiles (Preformed fragments, AP mine and blast wave interaction) and various targets were shown (see appendix F 5)

7.3 Penetration of Tungsten Carbide into steel targets (John Moxnes)

The purpose of this presentation was to show that the simulated penetration capability is dependant on the numerical solver. it was explained that the J-H damage model appears to be suitable for modelling the fracture of tungsten carbide although plasticity is not accounted for. Only the Euler solver is now used. (see appendix F 6)

7.4 Methods for simplifying 3D penetration simulations (Jan Arild Teland)

To simplify 3D penetration simulations, a virtual target can be used. A subroutine is then used to determine the boundary conditions at the projectile surface. In practice this means that only the projectile is modelled. The boundary conditions are calculated from the cavity expansion theory. (see appendix F 7)

7.5 Protection of soft skin vehicles (Ove Dullum)

This presentation described the up-armouring of light vehicles used in combat areas. It described which sections of the vehicle were to be upgraded and how it was designed. It also showed how the forces can still incapacitate the occupant even though a vehicle is armoured. (see appendix F 8)

7.6 Future trends in energetics (Adam Cumming)

More focus is being placed on Insensitive Munitions, not only because they are safer to use and store, bur also because they are more likely to survive a terrorist attack. Adam Cumming then went on to tell more about novel explosives and new developments e.g. AND, FOX7, FOX12, CL20, N_5^+. (see appendix F 9 and F10)

7.7 Life time assessment (Toren Karsrud)

The presentation was about the life time assessment of Norwegian missiles. During the presentation, the Norwegians expressed the interest of cooperation on this subject and were especially interested in policy papers from other countries on life time assessment. (see appendix F 11)

7.8 Update UK life assessment (David S Tucker)

The presentation was given by Mark Wasko on behalf of David Tucker. It focussed, among others, on the 6 controlled temperature storage facilities being built in Iraq. Also, remarks were made stating that ammunition stored in the open can be cooler than ammunition stored in ISO containers. (see appendix F 12)

7.9 Reassessment of Dutch EOD safety distances (Howie Lodder)

Howie Lodder presented the results of the TNO trials in Norway which were conducted under the ANNC agreement. These trials were to find fragmentation distances for MK 82 aircraft bomb for different test set-ups. Open air tests, sand cover and a protective structure utilising ISO containers were tested. (see appendix F 13)

7.10 TNO's urban warfare simulations (Maarten Manders)

Maarten Manders presented an overview of the projects currently running at TNO-PML in the field of Urban Warfare. The purpose of this programme is the development of knowledge, skills and infrastructure to quantify and/or qualify the operational effectiveness of small unit operations in the spectrum of peace support operations. (see appendix F 14)

7.11 NL status regarding DEW (Jurgen Timpert)

The presentation was split up into Particle beam weapons, High Energy lasers and High Power Microwaves. It described both systems, and named some examples and described the on-going research at TNO. Furthermore, it described possible future systems which could be fielded in the not too distant future and what future research topics could be at TNO in this area. This included associated vulnerability issues like the vulnerability against HPM weapons. (see appendix F 15)

The FFI representative commented on the Norwegian activity in this field. It seems that a collaborative effort between the Netherlands and Norway may be fruitful.

8 TOPICS FOR FUTURE COLABORATION

Based on the investigations in the individual countries and on the discussions during the meeting, the following topics were proposed for future colaboration projects.

1. Different aspects of fuzing. Topic for discussion between NL and UK
2. Aging of MTV (Magnesium, Teflon, Viton – a pyrotecnic flare composition)
3. Electric armour or Walker plates. There are possibilities for information exchange between NL and UK
4. High performance microwaves (HPM) and directed energy weapons (DEW). There is a possible project between NL and NO.
5. Energetics. Topic for discussion on the next meeting.
6. Nano-materials in energetics. Armour applications are not intended here.
7. Scalable munitions

9 TERM OF REFERENCE

A possible set of terms of reference was presented by Adam Cumming were discussed and found general acceptance. These are included in appendix C.

10 OTHER BUSINESSES

Dates for the 2005 meeting were not fixed, but it will probably be the first or third week of June. The meeting will hosted by UK.

A long-time delegate of the WGIII, Jan van Gool, was heading for retirement beginning 1st October 2004. The group has appreciated is valuable contributions and wishes him a happy retirement.

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B AGENDA

23 Sept

0830	Pick-up of delegates at Olavsgaard Hotel
0900	Welcome
0910	Minutes of the 2003 Meeting
0930	Update on national situation (NL, NO, UK)
1015	Ceramics protection (Pickup)
1035	Coffee break
1050	Encapsulated ceramics (v d Voorde)
1110	Penetration of tungsten carbide into steel targets (Moxnes)
1130	Protection of soft skin vehicles (Dullum)
1150	Methods for simplifying penetration calculations with hydrocodes. (Teland)
1210	Lunch
1250	Annual reports on collaborative projects
1530	Transport to social events in Oslo
1900	Dinner D/S Louise, Oslo

24 Sept

0830	Pick-up at Hotel
0900	Future trends on Energetics (Cumming)
0920	Life time assessment (Karsrud)
0940	Whole life time assessment (Wasko)
1000	Reassessment of Dutch EOD safety distances (Lodder)
1020	TNO’s urban warfare simulations (Manders)
1040	NL position on DEW (Timpert)
1100	Wrap-up issues
1200	Lunch
1230	Time for remaining issues if needed
1400	Latest time of transport back to airport

C PROPOSED TERMS OF REFERENCE

ANNC Working Groups

Proposed Terms of Reference

Purpose

Each Working Group is intended to provide a coherent means of exchanging information, and developing and monitoring collaborative programmes within its technical area.

Its operations should complement activities within other fora and focus on integration of technology within its context. Small scale scoping programmes amongst the three participants may lead to greater collaborative activities within this or other fora.

Management and Operations

Each Working Group will have National Leaders from each participant. Technical experts as required may support the National Leaders for the subjects under discussion. The host nation will chair the meeting and each participant will host the meetings in turn. The host will also provide the secretary and produce the minutes.

Each group will meet formally once a year to exchange information on subjects agreed prior to the meeting and to review collaborative activities (CP). Reports on CP activities should be agreed amongst the participants and circulated prior to the meeting.

Links will be maintained with other WG including provision of minutes and reports. Joint programmes are encouraged.

Meetings will also review and revise the strategy of the WG and decide the priorities for the next year. These will be reported to the Principals together and outline of progress and any issues that need to be resolved.

Scope of WG3

Energetic Materials and Munitions

Covers all aspects of Energetic Materials

> Explosives; Gun Propellants; Rocket Propellants; Pyrotechnics; Initiators
> Synthesis; Formulations; Performance; Life Cycle; Modelling; Disposal; Environmental Aspects

Covers Applications of Energetics

> Warheads; Gun and Missile Propulsion
> Systems Engineering Aspects of the applications including modelling and some aspects of OA where directly applied to the munition.
> Protection Systems including Armour and Fortifications; Mine Systems

D ANNUAL REPORTS

The following CPs have issued an annual report

- CPIII-5b Mechanical Ageing of Rocket Propellants
- CPIII-13 MINEN model
- CPIII-14 Air Target Vulnerability (see CPIII-24)
- CPIII-17 Protective structures
- CPIII-19 Optimisation of Exploding Foil Initiation of IM Explosive candidates
- CPIII-20 Study of dwell phase phenomena of ceramics during impact
- CPIII-21 Mitigation of Blast and Fragment Hazard
- CPIII-22 Close Action Environment (CAEn)
- CPIII-23 IUSS
- CPIII-24 Aircraft Vulnerability
- CPIII-26 Secondary Flyers
- CPIII-27 Close Combat Modelling

D.1 ANNUAL REPORT OF ANNC CPIII-5b

a. CPIII-5b Mechanical Ageing of Rocket Propellants

b. Chief Liaison Personnel

UK: Mr Dave Tucker (Dstl Fort Halstead)
Dr Dave Tod (QinetiQ, Fort Halstead)

NL: Mr Huub Keizers (TNO-PML)
Mr. Gerhard Reeling Brouwer (TNO-PML)

NO: Mr Greger Johansen

c. Reports exchanged

None

d. Meetings/Visits

No formal meetings have taken place in the last year. Discussions on possible (active) continuation of previous cumulative damage work has been held in the sideline of other joint NATO activities (AVT-119).

e. Progress/description of activities

NL activity (TNO-PML)

A significant amount of work has been performed on the ageing of solid propellant rocket motors, using motor analogues. Activities include chemical and mechanical ageing modelling, sensors, specialised testing techniques, etc. Results of this work has been discussed with Mr. D. Tucker (DSTL) and Mr. J. Theobold (QinetiQ). Furthermore work on crack-testing under motor conditions (pressurised) have been addressed.

f. Future activities

TNO and QinetiQ would like to set-up a joint effort (possibly including Norway), in the field of life assessment of rocket motors, focussing on cumulative damage of solid propellant rocket motors. Details and funding are tbd (see item g).

g. Matters of note

Due to personal circumstances the planned meeting on the way-forward has been delayed a number of times, but both parties still consider this topic very worthwhile (modelling of cumulative damage and crack growth / crack prediction) for further joint activities. A meeting is planned for the end of this year to try to define a programme of work.

The final report of the foregoing activity is waiting for the planned meeting (Keizers/Tod) to occur.

D.2 ANNUAL REPORT OF A/NL/N CPIII- CP13

a. Project title and identity

CPIII-13 MINEN Model

b. Chief liaison persons

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NL: Jean-Pierre Piereij

NO: Einar Ostevold

c. Reports exchanged

d. Meetings and visits

e. Progress/description of activities

There has been a single contact in 2004. The situation in the UK remains unclear. The action on the UK POC to host a meeting has not been completed. No information has been forthcoming with regard to the MINEN model issues with QinetiQ concerning support, packaging and licensing of the model. There is still an interest on the part of the Netherlands to discuss possible collaboration and/or release of the MINEN model.
The UK WGIII national leader has been approached.

f. Future activities

g. Matters calling for special attention

h. Remarks, suggestions

D.3 ANNUAL REPORT OF A/NL/N CPIII-17

a. Project title and identity

Protective Structures

2001-3 UK/Aus 27te trial Sept. 2002 (UK/Aus Defence Trial 840)
2001-3 UK/Aus 5te trial Sept. 2002 (UK/Aus Defence Trial 840)
2001-19 UK/Aus 5te trials May 2004 (UK/Aus Defence Trial 845)

b. Chief liaison persons

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c. Reports exchanged Final trial layouts have been exchanged and discussed.

d. Meetings and visits Various meetings with 5 ton trials participants (including UK and NL) in Woomera, SA, in the period that both trials were conducted (May 2004).

e. Progress/description of activities. UK/Aus Defence Trial 840 (27te and 5te trials, 2002) were succesfully conducted. Scientific reports with trials results were finished for three assignors:
TNO report entitled “Measurement setup and results of the 27 tonne explosion test” for UK/MoD/DOSG (POC: Mr. C.A. Hoing).
TNO report entitled “5 tonne explosion trial, Pressure measurements inside trenches” for DSTL (POC maj. R.P. Sheldon).
TNO-reports “Safe field storage of ammunition and explosives” for NL/MoD (POC Kol. A.P. Coppens).

In May 2004, two new 5 tonne (bare charge) trials took place in Woomera, SA. NL participated again in the trials and made use of the explosion effects to further investigate:

- Interaction of explosion effects on acceptor magazines (collaboration with GE/MoD);
- Interaction of explosion effects with POL-installation and 20ft containers (collaboration with DRDC Suffield).

The results are now being analysed and reported. Norway was not involved in these specific tests.

f. Future activities Final reports on both 5 tonne trials will be exchanged (mid 2005). The UK/MoD/DOSG and Aus/DoD are planning to do 2 more full-scale trials in May 2006 in Woomera, SA. Participation of NL is again offered.

g. Matters calling for special attention -

h. Remarks, suggestions Investigate how the future UK/Aus trials (2x 5 ton bare charge detonation) can be used to validate our prediction tools (on explosion effects and -consequences). POC UK: Mr. C.A. Hoing, UK/MoD/DOSG.

D.4 ANNUAL REPORT OF A/NL/N CPIII-19

a. Project title and identity

Optimisation of Exploding Foil Initiation of IM Explosive candidates

b. Chief liaison persons

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NO:

c. Reports exchanged

Report on 'Material Characterisation of the IM Explosive candidates' due to be distributed shortly (UK-report)

Report PML 2004-A61: 'Characterisation of the properties of some explosive candidates for use in Exploding Foil Initiators" . (NL-report) will be distributed shortly

d. Meetings and visits

No meetings and visits

e. Progress/description of activities

Experimetally some velocity measurements have been done with a new designed technique to acellerate the the flyers. The flyer velocities were limited to about 3.5 km/s for the 25 micrometer flyers. This was not enough for the explosives that have to be characterised. This is a problem that needs more attention.

f. Future activities

Work will be continued according to programme plan

g. Matters calling for special attention

A solution has to be found to achieve higher flyer velocities for the 25 micrometer flyers.

D.5 ANNUAL REPORT OF A/NL/N CPIII-20

a. Project title and identity

Dwell phase of Ceramic during Impact
ANNSC5 WG3 CP III- 20, DSTL ID. 05/056

b. Chief liaison persons

UK: I M Pickup Physical Sciences and, B, J James DSTL, Physical protection Group, Building 352, Porton Down, Salisbury, SP4 OJQ

Tel: 44 0(1)980 61 4912 (IMP)50 (BJJ) 6696 (IMP)
Fax: 01344 75 6745
E-Mail: bjjames@dstl.gov.uk ,
impickup@dstl.gov.uk

NL: A Diederen and M van de Voorde Munitions Effects and ballistic Protection, TNO, Lange Kleiweg 137, PO Box 45, 2280 AA Rijswijk, The Netherlands.
peskes@pml.tno.nl
tel:31 15 284 34 49 (GJP)

NO:

c. Reports exchanged

I M Pickup, A K Barker, I D Elgy, G.J.J.M. Peskes and M van de Voorde,
The effect of coverplates on the dwell characteristics of silicon carbide subject to KE impact, 21st International symposium on ballistics, Adelaide, 2004.

d. Meetings and visits

1 April 04 at DSTL

e. Progress/description of activities

- The programme has been completed
- More than 80 shots have been conducted in Stage 3: Influence of target configuration on dwell
- Significant effects of geometry on dwell have been measured
- Methods for measuring dwell have been developed
- A joint paper has been presented to the Int.Ballistics symposium
- A new programme has been proposed which will develop the CP III 20 programme to allow an analytical/empirical model of ceramic behaviour subject to KE threat. The programme has provisionally been agreed by PML Dstl and FFI. The proposal is to be presented at the 2004 ANNSC annual meeting in Norway in September 2004.
- Several other topics were considered for collaboration during the April 2004 technical review meeting at Dstl, Salisbury

f. Future activities

A new programme is being proposed to foll0w on from CP III-20, Ballistic analysis and modelling of ceramic armour subject to KE threat. This has been provisionally agreed with PML (Martin Van de Voorde,) and FFI (Ove Dullum)

g. Matters calling for special attention. None

h. Remarks, suggestions

The CP III-20 generated very useful data.

D.6 ANNUAL REPORT OF A/NL/N CPIII-21

Collaboration Project ANNC WGIII-

a. Project title and identity
2001-7 Mitigation of Blast and Fragment Hazard

b. Chief liaison persons

UK: **Maj R P Sheldon RE**

Tel: +44 (1252) 374061
Fax: +44 (1252) 374227
E-Mail: rpsheldon@dstl.gov.uk

NL: **Dr Louk Absil**

Tel: +31 (15) 284 3395
Fax: +31 (15) 284 3954
E-Mail: Absil@pml.tno.nl

NO: **Asbjorn Oddan**

Tel: +47 (63) 80 7531
Fax: +47 (63) 80 7509
E-mail:

c. Reports exchanged

d. Meetings and visits

August 2003: Visit by TNO-PML to Hjerkinn test site to perform trials using six MK 82 bombs.

e. Progress/description of activities

TNO has conducted fragmentation trials with 500 lb. MK 82 bombs at the Hjerkinn test site (NO). NO kindly offered the use of the Hjerkinn test site for these trials and the services of Asbjørn Oddan without whom it would have been impossible to conduct the trials.
The trials involved the recovery of fragments from the MK 82 bombs in different test set-ups. This included the testing of sand cover, the evaluation of the ISO container construction to mitigate fragmentation + blast and two open air tests.
The first report describing the test results has now been finalised including the preliminary results and the proposed safety distances for the MK 82 bomb in different situations. This draft report is now being evaluated by the Dutch EOD.

f. Future activities

The final report is currently being written and will include the proposed safety distances for a range of ammunition articles including WWII bombs.

g. Matters calling for special attention

h. Remarks, suggestions

TNO would like to know what experience the other countries have in determining safety/fragment distances for rogue fragments.

D.7 Collaboration Project ANNC WG III-22 on CAEn (UK/NL)

a. Project title and identity

CP III-22: Close Action Environment (CAEn) (UK/NL)

b. Chief liaison persons

NL: Mrs. E.N. van Son-de Waard TNO
UK: Mr. Nick Stanbridge DSTL

c. Reports exchanged

d. Meetings and visits

e. Progress/description of activities

No activities. There is no plan or need to use this mechanism for collaboration. The UK-NL collaboration in this field currently takes place under the TTCP umbrella.

f. Future activities

This CP will be concluded.

g. Matters calling for special attention

h. Remarks and suggestions

D.8 Collaboration Project ANNC WG III-23 on IUSS (NO/NL)

Annual report 2003-2004

a. Project title and identity

CP III-23: Integrated Unit Simulation System (IUSS) (NO/NL)

b. Chief liaison persons

NL: Mrs. E.N. van Son-de Waard TNO
NO: Mr. Einar Østevold FFI

c. Reports exchanged

d. Meetings and visits
There has been one meeting discussing the benefits of IUSS.

e. Progress/description of activities

No further activities. Norway has not received IUSS. The NL international activities in this field currently take place under the TTCP umbrella, with the US and the UK as main collaborators. In addition a new project arrangement with the US is about to be signed. This leaves no room for a separate collaboration with NO.

f. Future activities

This CP will be concluded.

g. Matters calling for special attention

h. Remarks and suggestions

D.9 ANNUAL REPORT OF A/NL/N CPIII-24 (previously CPIII-14)

a. Project title and identity

Air Target Vulnerability

b. Chief liaison persons

UK: **Pat Collins, Missiles & Countermeasures Dept, Dstl Farnborough**
Tel: **+44-1252-455066**
Fax: **+44-1252-455083**
E-Mail: **pwcollins@dstl.gov.uk**

NL: **Eelko Van Meerten, Weapon Effectiveness, TNO-PML**
Tel: **+31-15-2843268**
Fax: **+31-15-2843991**
E-Mail: **meerten@pml.tno.nl**

NO: **Not represented**

c. Reports exchanged

Electronic copies of several presentations have been delivered to TNO by Dstl as follows.

Description of Dstl vulnerability modelling methodology and software tools, including INTAVAL and WISADS, used for assessment of air target vulnerability.

Programme investigating structural vulnerability of UAV targets against MANPAD type warheads, funded by ARP 05.

Final presentation on Item 5 of CRP Tri-Service Vulnerability program investigating damaging effects of Blast/Fragment synergy from Anti-Air warheads on targets. Presentation contained two parts, one from Dstl giving outline approach and forming way ahead, another produced by QinetiQ (under contract to Dstl) describing detail hydrocode investigations into synergy.

An electronic copy of a Finite Element Model of a multi spar fighter wing (Mig 29) in ANSYS format has also been supplied.

An electronic copy of a late draft version of the TNO report on the firing trials conducted against the F-16 at Shoeburyness in March 2000 has been supplied to Dstl. The final version of this report is not yet available.

d. Meetings and visits

Derek Taylor & Matthew Cork attended a two day meeting at TNO during May 2004 to discuss a potential work program for CPIII-24.

During the meeting Derek Taylor presented work on UAV vulnerability and Blast/Fragment Synergy and Matthew Cork presented Dstl's vulnerability modelling software.

TNO provided details of their DAMINEX model which it was felt could form the basis of an air target structural damage model. Discussions centred around the representation of damage cases within the model.

e. Progress/description of activities

The meeting held in May 2004 explored several areas of interest for furthering the collaboration. TNO were keen to extend their DAMINEX model to cover structural damage to aircraft. After discussion it was decided that this would not be feasible without a substantial amount of fundamental research into a new failure criterion to be applied to aircraft structures.

Discussions also took place on the subject of CFRP vulnerability and centred around the UK UAV vulnerability programme and Blast/Fragment Synergy. No common programme could be identified in these areas which could be incorporated into the collaboration in a realistic timeframe.

The provision of a further Dutch F16 for use in vulnerability trials was discussed and an airframe could be supplied for use in future UK based trials. A provisional trials date for static warhead firings is March 2006 with dynamic firings using the Pendine Long Test Track in 2007.

After more discussions on modelling collaboration an agreement was reached that Dstl could supply a Finite Element Model of a multi sparred fighter wing. This could then be used by TNO to examine cases of weapon induced damage.

It is considered that CPIII-14 has now reached a natural conclusion.

f. Future activities

Following the May meeting it is proposed that one of the strands previously identified is run as a collaborative activity as follows.

FE Modelling of structural damage of air targets

- Dstl & TNO will jointly develop a new model to assess structural kill capabilities of guided weapon warheads (fragment effects) against air targets, the model will likely be known as ANSKAT (Anglo Netherlands Structural Kill of Air Targets).
- To support this activity Dstl will provide structural models of targets in FE format and damage cases to apply based upon its trials database.
- TNO will use the target models and damage cases to investigate effects on targets using FE modelling.
- TNO & Dstl will jointly use the FE results to develop simple rules for assessment of structural kill and incorporate these into a modelling tool.
- The modelling tool will be developed either by a single external contractor or jointly 'in house' by Dstl & TNO.
- Activities in the Dstl trials programme will be designed to provide validation data that is specifically tailored to the needs of the model developers.

- ANSKAT would be jointly owned with joint IPR. It is assumed that Dstl would have free use of the model but would not be allowed to release it further without advanced permission from TNO. Data generated in the programme will be jointly owned and other supporting software needed to run assessments will be shared (e.g. target models, damage cases, WISADS , FRAGSTRUC)

Further work

- It is proposed that the potential of developing DAMINEX to model blast effects against air targets is considered. This would require the development of a new failure criterion to use in assessing damage to aircraft structural materials. This work would probably be best done in academia and possible collaborators would be Imperial College London, Oxford University and TU Delft.
- There is also interest in investigating aerodynamic effects in terms of flutter instability due to the damaged structure and the transient effects of impact on flight profile.
- A further area for investigation could be the secondary damage inflicted on targets by aerodynamic forces acting on damaged structures.
- TNO could supply further F16 targets for use in Dstl's trials programme in conjunction with the modelling programme described above.

g. Matters calling for special attention

CPIII-14

- No final report has been produced covering the whole of CP.14.
- The work conducted in the UK during the F16 trial is described in a DERA report (CON), details have been provided to TNO but the complete report includes UK EYES only material.
- The single fragment firings are described in a QinetiQ report (RES); again this report covers a wide range of activities some of which are UK/US/GE EYES only. The relevant sections have been supplied to TNO.
- The BAE SYSTEMS report on the gas gun firings has been provided to TNO.
- An electronic copy of a late dreft version of the TNO report on the F-16 trials has been provided to UK.

CPIII-24

- Some progress has been made in defining a suitable follow on programme, it is envisaged that a formal TOR for this work will be produced soon.

h. Remarks, suggestions

Dstl will produce draft summary report describing the work completed under CP.14 within the next 3 months and pass to TNO prior to formal issue.

Report Produced by: Pat Collins 16 September 2004

D.10 ANNUAL REPORT OF A/NL/N CPIII-26

a. Project title and identity

Secondary Flyers

b. Chief liaison persons

UK: Mark Wasko

Tel: +44 1959 892330
Fax: +44 1959 892511
E-Mail: mpwasko@dstl.gov.uk

NL: Ing. W Prinse

Tel: +31 15 284 3361
Fax: +31 15 284 3997
E-mail prinse@pml.tno.nl

NO:

c. Reports exchanged
None

d. Meetings and visits
None

e. Progress/description of activities
TNO-Progress
HNS –IV pellets were pressed but the density was too high. New pellets have been pressed. Some velocity measurements have been done but the experimental set-up was not sufficient. New experiments planned. Within the programme that funded this project there was not enough space to give more attention to the work.

f. Future activities
A meeting to discus the progress
Work to programme plan

g. Matters calling for special attention
None

D.11 ANNUAL REPORT OF A/NL/N CPIII- 27 Close Combat Modelling

a. Project title and identity

CP III –27 Close Combat Modelling

b. Chief liaison persons

UK: Dr Nick Stanbridge

Tel: 44 1959 892207
Fax: 44 1959 892504
E-Mail: nhstanbridge@dstl.gov.uk

NL: Mrs EN van Son-de Waard

NO: R. Lausund

c. Reports exchanged

UK transferred electronic documents relating to the CAEn model:
CAEn Functional Overview
CAEn GUI overview
CAEn Control Panel Overview

d. Meetings and visits
17th – 19th Sept 2003
UK / NL meeting to discuss close combat modelling and to install CAEn v9.3.0.11

e. Progress/description of activities

- Update on NL reorganisation.
- Update on NL experience of IUSS (US model).
- CAEn v9.3.0.11 was installed onto the Dutch network and demonstrated. Since this was the first exposure of the Dutch to the XP version of the model and the new interface, a short training programme was conducted.

f. Future activities
Once the NL analysts have had some experience with the new version of CAEn, a trilateral meeting will be held to examine collaborative opportunities in close combat modelling.

g. Matters calling for special attention
None

h. Remarks, suggestions
None

E DRAFT PROPOSAL ON CERAMIC ARMOUR

Draft

Ballistic analysis and modelling of ceramic armour subject to KE threat

Dstl – PML- FFI collaborative ANNC programme

Ian Pickup, Dstl (UK), Martin van de Voorde, PML (NL), Ove Dullum, FFI (NO)
2nd August 2004

1. Introduction

In the previous collaboration between Dstl and PML [*The dwell phase of ceramic during impact*, ANNSC 5 WG3, CPIII-20], the dwell phenomena (KE rod erosion on the impact surface of the ceramic target) in hot pressed silicon carbide SiC B and SiC N (Cercom inc.) was investigated. Methods for quantitatively measuring dwell were developed and effects of target geometry were determined. Considerable quantitative data was gained into the effects of ceramic target geometry on KE rod dwell. The experimental configuration used in the previous programme has provided results with a high degree of consistency but has some limitations to its relevance in practical armour solutions. This is primarily due to the use of semi-infinite backing on the ceramic tiles, massive lateral confinement and the single experimental round used (FNC tungsten alloy, 5 mm diameter, 20:1 aspect ratio).

To allow the design of ballistically efficient, practical ceramic armours to defeat KE threats (specifically, long rod penetrators), it is essential to understand and measure the effects of practical geometry and threat characteristics on dwell. The programme proposed below seeks to provide such data to allow the process of dwell and its termination to be modelled using empirical/analytical methods. This would form the basis of a design guide tool for developing practical ceramic armour for efficient protection of military vehicles against KE (long rod) threat. The experimental results will allow the development of advanced ceramic numerical models which include the role of penetrator dwell and its termination in addition to accurately predicting penetration and erosion rates. This will allow complex armour geometries to be assessed.

2. Objectives

2.1. Experimental Objective

Task 1 — To conduct a quantitative ballistic investigation into the performance of silicon carbide ceramic in confined, finite backed target systems subject to impact by a KE projectile. The out put of this task will be optimised to feed directly in to the development of the analytical/empirical model (Task 2)

Task 2 — To develop an analytical / empirical model of ceramic dwell characteristics relating performance to geometry and confinement of the ceramic, geometry of the backing support and the geometry of the

projectile. This will, in effect, serve the purpose of a design guide for developing efficient ceramic armour.

Task 3 To develop advanced ceramic material-failure models for use in hydrocodes which reflects the dwell and steady penetration behaviour of the specific ceramic material.

2.2. Programme outline

Task 1 Ballistic programme: Dwell measurement of finite ceramic targets

It is envisaged that this programme will use the previous programmes' data as a baseline and extend the studies to include finite backed targets and rod scaling issues. In some cases, the targets may be instrumented with diagnostic equipment, like Flash X-ray or stress and strain gauges embedded in the target to determine conditions at the interfaces to provide information for the modelling phases.

Task 1.1 Rod scaling effects on standard semi-infinite backed SiC targets at normal incidence.
Parameters investigated: rod diameter, ceramic lateral dimensions, impact velocity

Task 1.2 Rod scaling effects on finite backed SiC targets at normal incidence.
Parameters: backing thickness, backing material, rod diameter, velocity, interface conditions (bonding method), stress transmission.

Task 1.3 Quantification of the effects of lateral dimension and lateral constraint.
Parameters: magnitude of lateral confinement stress, confinement materials.

Task 1.4 Dynamic axial confinement effects.
Parameters investigated: Cover plate configuration. Magnitude of axial stress.

Task 1.5 The effects of obliquity.
Parameters investigated: angle of obliquity, target thickness, backing thickness.

Completion date: 2 – 2.5 years from start

Task 2 Development of an analytical/empirical model for dwell termination.

Task 2.1 Review literature of existing models – design guides
Task 2.2 Define modelling strategy
Task 2.3 Develop model

completion date: 3 years from start programme end

Task 3 Development of an advanced constitutive/failure material model

Task 3.1 Review existing material models
Task 3.2 Define modelling strategy
Task 3.3 Develop model

Completion date: ?? (3 years from start programme end)

Costs

It is envisaged that 15/20 ballistic shots a year plus modelling effort would cost each participant approximately 60,000 Euros /year

Workshare

It is envisaged that the costs be shared equitably between the participants. The allocation of work per task will be organised in a project scheme, which would including a test matrix.

Milestones and deliverables:

Milestones and Deliverables will be discussed in more detail in the discussion of the allocation of work

Reviews

The progress of the overall programme should be reviewed by the participants twice a year. It would be desirable for further meetings or communication on specific topics throughout the year.

F PRESENTATIONS

Some of the presentations contain video clips. They are reproduced herein. However, they are found on the CD accompanying this report.

The presentation are given in chronological order as presented at the meeting

Please note that parts of some of the presentations from TNO-PML are not properly reproduced as their Microsoft Powerpoint templates contain liscensed TNO-fonts. When converting to pdf-format these fonts appear in an unrecognizable form.

F.1 TNO defence, security and safety – Maarten Manders

Core area developments

TNO Defence, Security and Safety
Unity in diversity

WQR Ghihqfh/Vhfxul'| dqg Vdih'|

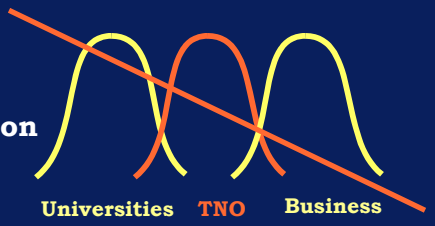
Paul Korting (presented by Maarten Manders) Vhs'hp ehu 5337

TNO Mission

To apply scientific knowledge with the aim of strengthening the innovative power of industry and government

A Changing World brings Changes for TNO

- … growing complexity
- … economical problems
- … importance of innovation
- … internationalisation
- … innovation paradox
- … increased R&D sharing

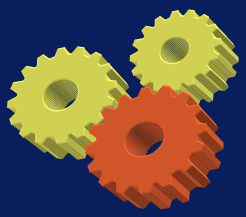


Abandoning the bridging metaphor in favour of a networking model

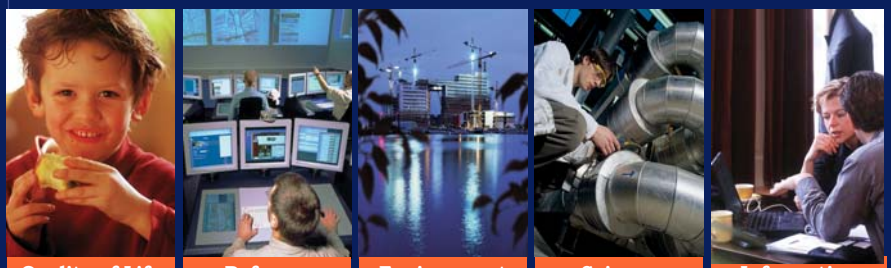
TNO is well-respected, with a strong technology position …

but too slow in getting technology to the market …

and therefore failing industry and government in its mission



The New TNO
Five core areas, no more institutes



Quality of Life	Defence, Security and Safety	Environment and Geosciences	Science and Industry	Information and Communication Technology

Mission and Vision
The short versions

- **FEL** *Making information work*
- **PML** *Committed to innovation for a safer world*
- **TM** *Improving human performance in demanding environments*

TNO Defence, Security and Safety Preliminary Mission and Vision

Mission

- Committed to innovation for a safer w

Vision 2010

- Society acknowledges that o cts and technologies contribute to making t nds a safer place
- We are a strategic p the NL MOD concerning security and ef issues
- We are on ost European organisations and an excell in leading international alliances
- We a ccessful market-oriented organisation a echnology together with industry in in products

to be given a more concrete form ...

TNO Defence, Security and Safety Organisational Structure (1/4)

Current characteristics

- Profitable
- Strong customer relations
- Market expansion
- Capacity bottleneck
- Hybridity is a problem

New approach

- Limited change in structure
- Drive to business development
- Keeping everything together
- Managed growth

Organisational Structure (2/4)

Abstract trade-off

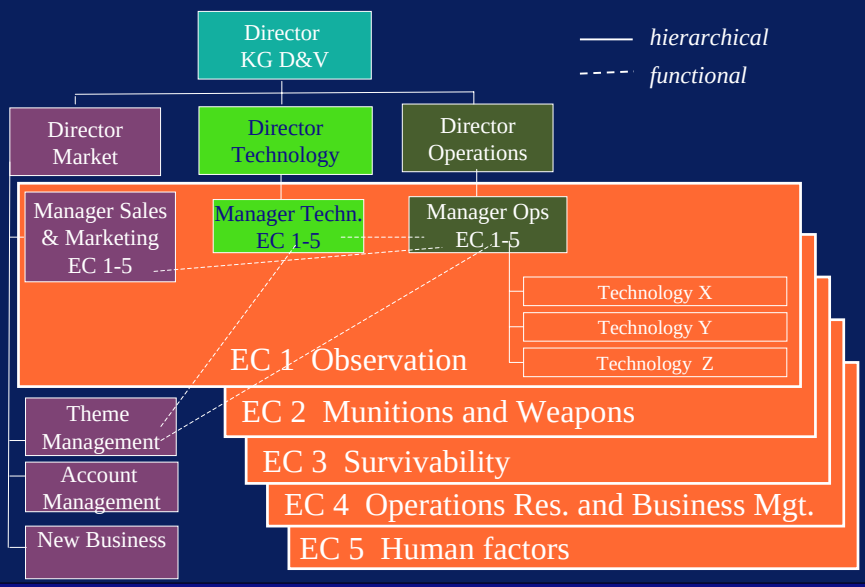
- Integral delegation of authority: simple organisation at the cost of unclarity towards market
- Separation of responsibilities: clarity towards market at the cost of more complex internal mechanisms

'

Organisational Structure (3/4)

- **No more integral responsibilities below core area level**
- **Core area director, plus operations director, market director, technology director**
- **Operations responsible for project execution, resource management, capacity planning, capacity and project results**
- **Market responsible for intake of turnover and sales result**
- **Technology as internal principal for technology projects**

Organisational Structure (4/4)



TNO Defence, Security and Safety Market Development

Primary market areas

- **Defence**
- **Security and Safety**
- **Air and Space**
- **Maritime**

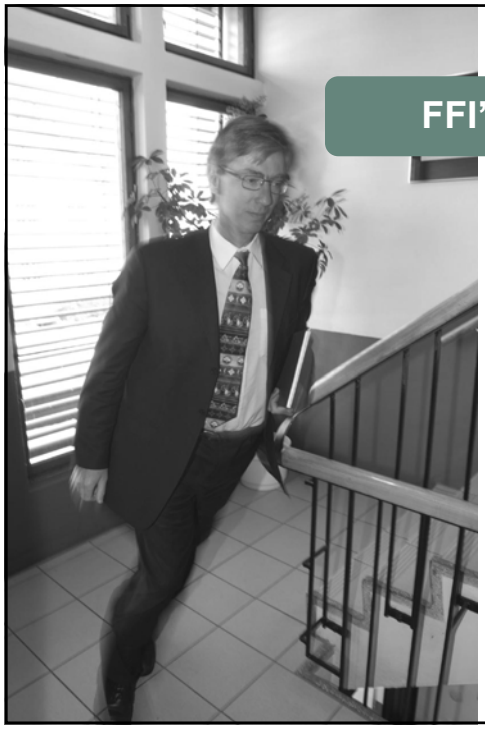
F.2 Status of FFI – Bjarne Haugstad

FFI Forsvarets forskningsinstitutt

Norwegian Defence Research Establishment

Norwegian Defence Research Establishment

Established April 11th - 1946



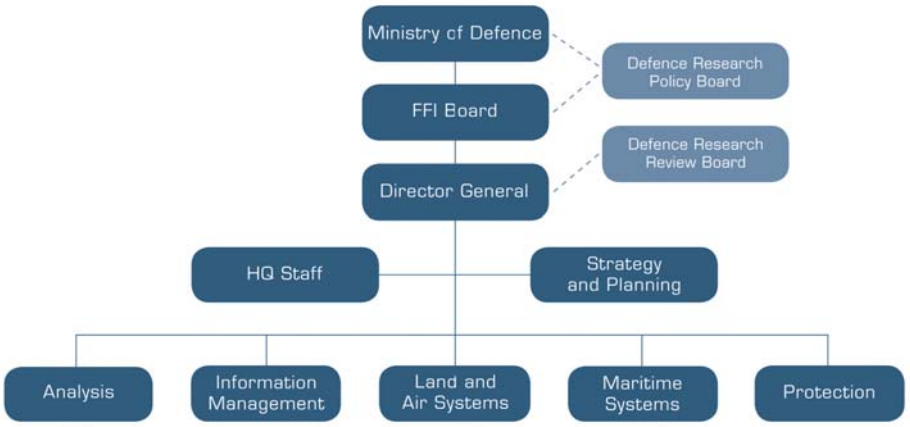
FFI's Charter

- Give advice to the MoD and the Chief of Defence on the potential implications of scientific technical development.
- Advice on the best use of military technology for Norwegian defence purposes.
- Undertake development of weapons and equipment as a basis of competitive national defence industry.
- Investigate geophysical areas of importance to defence.
- Contribute to the national scientific and technical, and to industrial development.

Forsvarets forskningsinstitutt

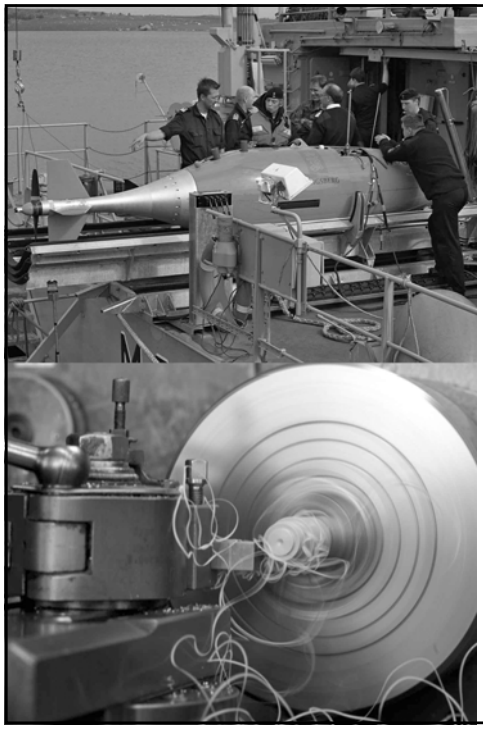
- Staff nearly 600 (all civilians)
- More than 400 scientists and engineers focus their collective energies to develop knowledge and technology for Norway's and international security
- Annual turnover 500 MNoK (2003)

FFI's organisation



Defence Research Policy Board (FFR)

- Chief of Defence
- Director General, Department of Defence Policy and Long Term Planning, MoD
- Director General, FFI
- Commander National Joint Headquarters
- Director General, Defence Logistic Organization
- Five appointed civilian members
- Observers from Defence Staff and MoD



Defence Research Policy Board (FFR)

The five appointed civilian members (2003-2006)

- Executive Vice President Elisabeth Berge, Statoil
- Vice-Dean Åse Krókje, Norwegian University of Science and Technology
- Executive Vice President Marit Døving, Consorte Group ASA
- Director Erik Skaug, The Research Council of Norway
- Foreign Correspondent Anne Cathrine Løchstøer, Norwegian Broadcasting System

FFI's board 2003 - 2006

Special Council
Johan C Løken (M.P.C.)
Chairman

Director
Ingvild Myhre
Vice-chairman

Institute leader
Frøydis Langmark

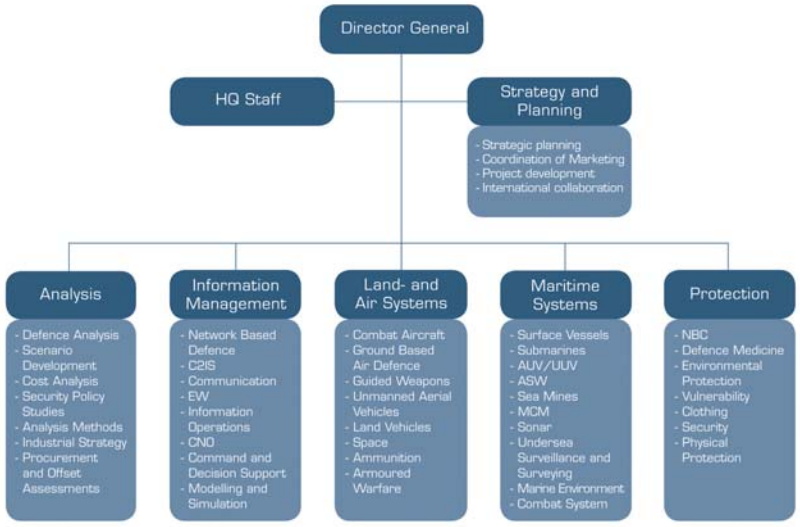
Principal Engineer
Ulv Skafle

Director
Walter Langrud

Scientist
Vivianne Jodalen

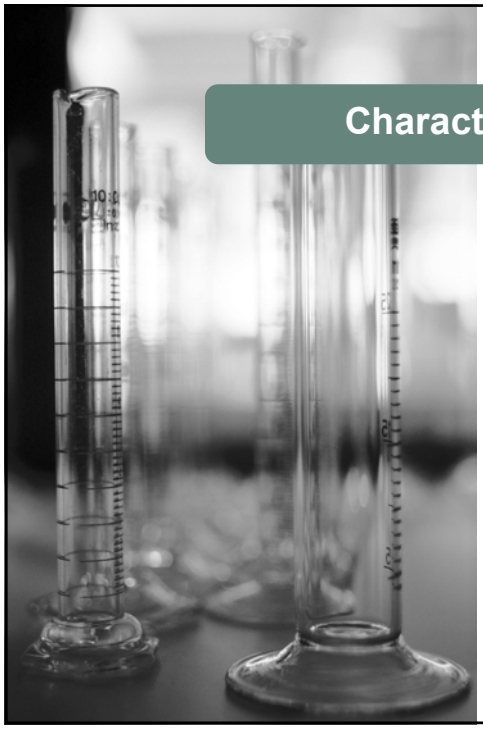
Professor
Arild Rødland

FFI's organisation with areas of research



International collaborations

- Participation in NATO RTO
- Collaborations with national and international industry and government laboratories in WEAG projects
- Bilateral collaboration projects with USA and others
- Tri-lateral collaboration projects with UK and NL under ANNCP
- Nordic collaborations
- Ad hoc collaboration with other defence R&D laboratories
- Participation in the international scientific community



Characteristics

- Only major defence R&D organization in Norway
- Project organization
- Long and short term orientation
- Joint planning and R&D between FFI, MOD and Defence Staff (FST)
- Close relations and co-operation with the procurement agency (FLO)
- Co-operations between MOD, FLO, FFI and industry in concept, development and production phases

F.3 MOD research strategy – Adam Cumming

MoD Research Strategy

Dr A S Cumming
Dstl
Fort Halstead

Corporate Research Programme

ADVICE IN HEAD OFFICE

1. Advice to Ministers	*Advice to Ministers & Head Office on strategic and sensitive issues*	CSA
2. Advice: policy & planning	*Advice and analysis to support MOD's strategic planning processes*	Policy Director
3. Advice: capability management	*Advice and analysis to support capability management in the ECC area*	DCDS(EC)

WIDER ADVICE

4. Advice: availability	*Investing in ensuring that people across MOD have access, now & in the future, to expert advice*	S+T Director
5. Advice: technology awareness	*Advice across MOD on global S+T advancements & their relevance to MOD business*	S+T Director

TECHNOLOGY

6. Technology: in the supplier base	*Investing in getting the right technology of the right maturity into the right supplier base at the right time*	DCE/DPA
7. Technology: innovative solutions	*Harnessing S+T advancements to provide innovative solutions to defence challenges*	DCDS(EC)

Corporate Research Programme

Past Strategy Approach

- MoD Technology Strategy
  - Category I - MoD lead
  - Category II - MoD collaborates with others
  - Category III - MoD content to leave to others
- Useful guide but not universally adhered to
- Being superseded by top level S+T strategy plus Technology Domain Strategies

Changing Strategy for Research

- Level of Need has changed -
  - Expense / Breadth of S+T
  - Research Structure, Establishments - DERA - Wider Supplier Base
  - Procurement Process - wide supply base
- Technology awareness
- Understand technology and how to exploit it
- Influence technology to benefit MoD
- Control technology and the technology base.

Changing Strategy for Research

- Level of Need has changed -
  - Expense / Breadth of S+T
  - Research Structure, Establishments - DERA - Wider Supplier Base
  - Procurement Process - wide supply base
- Technology awareness
- Understand technology and how to exploit it
- Influence technology to benefit MoD
- Control technology and the technology base.

Changing Strategy for Research

- Level of Need has changed -
  - Expense / Breadth of S+T
  - Research Structure, Establishments - DERA - Wider Supplier Base
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Changing Strategy for Research

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  - Expense / Breadth of S+T
  - Research Structure, Establishments - DERA - Wider Supplier Base
  - Procurement Process
- Technology awareness
- Understand technology and how to exploit it
- Influence technology to benefit MoD
- Control technology and the technology base.

Addressing capability

- Research required to assess options to fill capability gaps and build business cases prior to initial gate.
- Same research can influence and advance the technology required to fill those gaps.
- Detailed technical strategy at any one time depends on combination of capability gaps and MoD's longer term and generic aspirations, and strategic drivers.

EGC Domain Strategy - Top level Drivers

- Qualitative edge over opponents
  - But interoperability with allies
  - Influence on developing top level IRC Strategy
  - Interact with the main players
  - Need for S&T Awareness on world-wide basis

Domain Strategy - Drivers and focus

- Affordable technology
  - Whole life of the CAMID cycle including ownership
  - Less manpower intensive operations
  - **Design for life / managed upgrades / disposal**
    - » Speed up technology insertion (**S+T Thrust**)
    - » Maintain technology edge over life
    - » "Open architectures"
    - » Manage redundancy / obsolescence
  - **Technology Insertion MPA**

Technology Insertion

- Not simply technology research required but approach to business processes, clearances and certification.
- MoD “Affordable Avionics” Strategy applicable to weapons as well as aircraft.
- Recent example - PUMA (Programmable Upgradeable Missile Architecture) by DEC TA. Now being taken on within the GW ToE as PrOTeUS.

Domain Strategy - Drivers and focus

- Trend to unmanned platforms
  - Linked to Manpower Efficiency **(S+T Thrust)**
  - **Autonomy**
  - Influence on weapons
    - » Rules of Engagement Issues
    - » Legal Issues
  - Flight clearance
  - Carriage and release of weapons

Domain Strategy - Drivers and focus

"Kursk"

- Discharge "Duty of Care"
  - Linked to **S+T thrust**
  - Expert status related to safety
  - Insensitive Munitions Policy / ALARP Principle
  - Environmental impact
  - Flight safety / clearance
  - Restricted rules of engagement
  - **Example of Focus across MoD** - Munitions Technology Research Working Group
  - Separate RBB "DU Programme"

Domain Strategy - Drivers and focus

- Rapid deployment and effect
  - Reduce logistic footprint
  - Platforms & Weapons lighter & smaller
  - Greater mission flexibility
  - No loss / increase Effectiveness and Survivability
    - » Example :- Electric Armour Concept
  - Multi-role weapons / seekers
  - "Intelligent" warheads / propulsion / system

Mission flexibility - greatest challenge for future missiles

- Cheap, reliable, flexible "Energy Managed" propulsion.

Rocket Motor ⟶ Performance / flexibility

PROPULSION SPECTRUM

Cost / reliability ⟵ Air Breathing

- Multi- effect warheads for wider target sets
  Fragmentation / blast/ SC/ EFPs
  Targets with DAS

"Smart weapon" for use but "Wooden round" for maintenance and "Intelligent" for life prediction.

Domain Strategy - Drivers and focus

- All weather capable / precision strike / low collateral damage.
  - Linked to **S+T thrusts**
  - All parts of conflict spectrum
  - Link guidance, control, seeker, fuze, terminal effect.
  - Rules of engagement
- Trend to small smart weapons,
  - reduced explosive content for same effect
    - » better for IM
    - » but more complex systems to own and manage

Trend towards Seeker Imaging

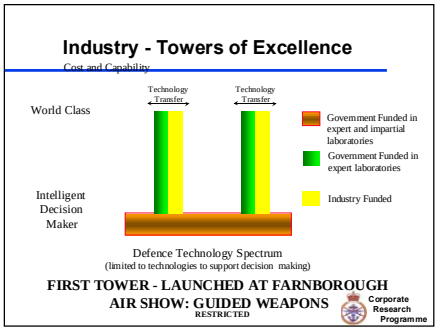
- Help discriminate between target types
  - Low collateral damage in Restricted ROE scenarios
  - Choose optimum detonation mode for multiple effect "intelligent warheads"
  - Differentiate between target, decoys and countermeasures
- Part of Guidance Integrated Fuzing approach
  - More effective Endgame against air targets
    - » No longer simple "stern chase" locking on engine exhaust
    - » Allows head-on and all angles approach
  - Choose optimum warhead burst point against all targets to maximise weapon effectiveness

Domain Strategy - Drivers and focus

- Effect of technologies at system level linking through to OA -
  - Hierarchical modelling approach from fundamental science models upwards.
  - Modelling and Experimentation integrated
    - » Hazard UK
  - Aims at assessing effect on military capabilities - aids trade off studies.
    - » E.g. IM versus systems performance not just explosives performance.

Domain Strategy - Drivers and focus

- Greater emphasis on Technology demonstration, risk reduction and transfer.
  - Increase exploitation of technology and knowledge



Guided Weapon Tower of Excellence - exploitation route for key weapon technologies

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Drivers - disruptive technologies

- Intelligent decision maker, including disruptive and “breakthrough” technologies.
  - Ability to predict & understand for own use and effect of use by opponents
  - Ability to exploit or counter, including effect on doctrine.
  - Future disruptive technologies roots in traditional military areas ? Or from military use of civil technologies ?

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Breakthrough technologies

- Existing EGC “Breakthrough Technology” Research
  - Enhanced Blast
  - Electromagnetic Launch
  - Hypersonics
- Possible areas
  - Super-caviting projectiles

Example of focus and co-ordination

- Munition Technology RWG
  - Align all work
  - Link to industry
  - Energetics - **What capability do we we afford in the UK ?**
    - » improve links to Nuclear programme
    - » International Links
    - » Synthetic chemistry becomes a technology awareness area
  - Feed into **GW ToE**
  - “Quick wins” Duty of Care / Ownership issues

Summary

- Need for fully integrated, coherent programme / strategy across multi-customer base.
- Co-operative working within MoD and with partners.
- Painful decisions
  - Intelligent Customer Status
  - Only develop technology where it gives greatest benefit / affordable.
- Need for Expert Customer Status on Duty of Care / Whole Life OME issues.

F.4 Ballistic analysis and modelling of ceramic armour subject to KE threat - Ian Pickup

ANNC WG3
Ballistic analysis and modelling of ceramic armour subject to KE threat

Dstl – PML- FFI Proposed collaborative programme

I M Pickup, Physical Sciences Department
Porton Down
Salisbury
Wiltshire SP4 OJQ
UK

Ballistic analysis and modelling of ceramic armour subject to KE threat

- Report overwiew of the recently finished programme
  - CPIII-20 Dwell phenomena in ceramics
- Review backgound data
- Introduce the proposed programme

ANNC WG3 CPIII-20 Dwell phenomena in ceramics

I M Pickup, B J James
Physical Sciences Department
Porton Down
Salisbury
Wiltshire SP4 OJQ
UK

G J Peskes, M van der Voorde
Munition Effects, Ballistic Protection
TNO, PML
Lange Kleiweg
PO. Box 45
2280 AA Rijswijk

CPIII-20: Dwell phenomena in ceramics

Objective:

to provide the understanding of the physics of the phenomenon to allow dwell to be harnessed in practical armour systems to increase ballistic efficiency significantly and **reproducibly**

The primary objective of this task is to assess the influence of the ceramic target configuration on dwell.

Particularly; the axial and lateral confinement and lateral dimension of the target.

The method of assessment of dwell will be based on depth of penetration of a semi-infinite steel back block.

The experimental methodology is a low risk method.

Work programme
June 2000-May 2003

The programme was divided into three tasks:

- Task 1: Development of methods to assess dwell (Nov 2001 complete)
  - Sensors
  - Comparative methods
- Task 2: Measuring transition from total defeat of the rod and commencement of penetration (Jan 2002 complete)
- Task 3: Effects of target configuration parameters on dwell phase (May 2003 complete)

CPIII-20 Ceramic dwell- Reports, meetings and exchanges

Reports:

I M Pickup, DSTL, *The dwell phase of ceramic during impact:Revised research proposal,* June 2001,

I M Pickup, A K Barker, I D Elgy, G.J.J.M. Peskes and M van de Voorde, *The effect of coverplates on the dwell characteristic of silicon carbide subject to KE impact,* Proc. 21st International Ballistics Symposium, Adelaide (2004).

Meetings:

Technical Meeting, DstlL Chertsey, June 2001

Technical Meeting, Dstl Chertsey, April 2002

Technical Meeting, PML Risjwick, April 2003

Technical Meeting, Dstl Porton, April 2004

CPIII-20 Ceramic dwell- Summary

- The programme has been completed
- More than 80 shots have been conducted in Stage 3: Influence of target configuration on dwell
- Significant effects of geometry on dwell have been measured
- Methods for measuring dwell have been developed
- A joint paper has been presented to the Int.Ballistics symposium
- A new programme has been proposed

Ballistic analysis and modelling of ceramic armour subject to KE threat

Dstl – PML- FFI Proposed collaborative ANNC programme

Ballistic analysis and modelling of ceramic armour subject to KE threat

- The programme objectives:
- To develop a capability to model analytically or empirically, the ballistic performance of high performance ceramics subject to KE long rod threats.
- This will in effect be a design guide for the use of ceramic armours in practical configurations where surface defeat of the threat is a key element to ballistic efficiency.

Ballistic analysis and modelling of ceramic armour subject to KE threat

- The programme will have three elements
  - 1) a quantitative ballistic investigation into the performance of silicon carbide ceramic in confined, finite backed target systems subject to impact by a KE projectile. The out put of this task will be optimised to feed directly into
  - 2) Analytical/empirical model. Design guide
  - 3) Development of material models which reflect the appropriate damage and failure behaviour.

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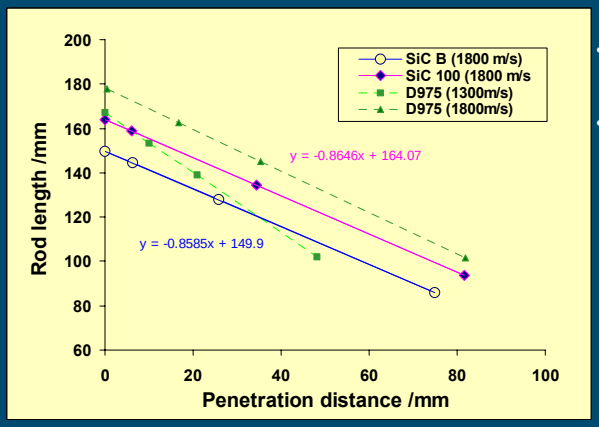
SWARF

- 3.2 MeV accelerating voltage , 50ns pulse width, 3mm spot size
- Penetrator S1-14

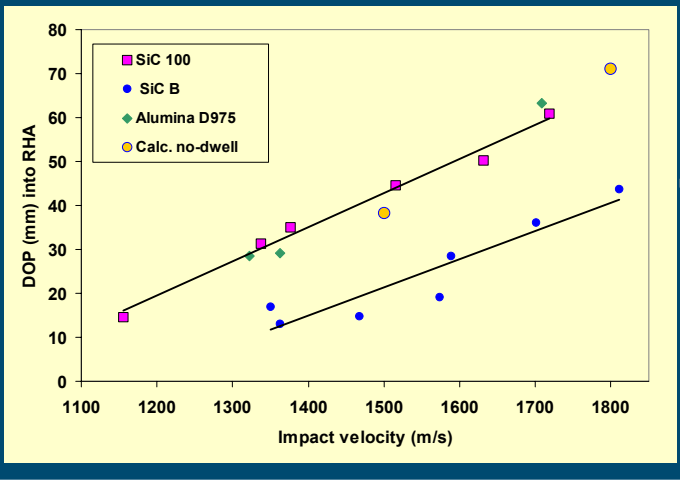
Erosion rate comparison
w.r.t. penetration length

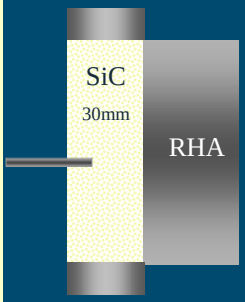


- **SiC100 and SiC B have equal erosion rates.**
- **SiC and alumina have equal erosion rates.**

Notes

Dwell or no dwell?





FNC tungsten Rod:

5mm ϕ x 100 mm

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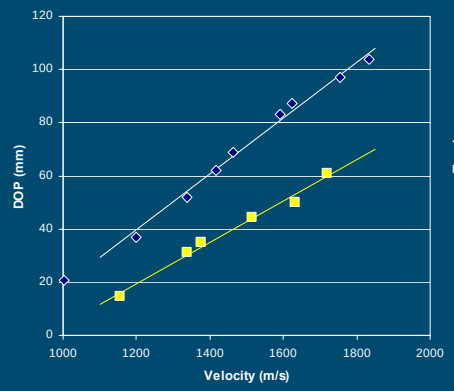
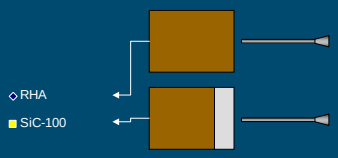
Effect of axial confinement, SiC-100





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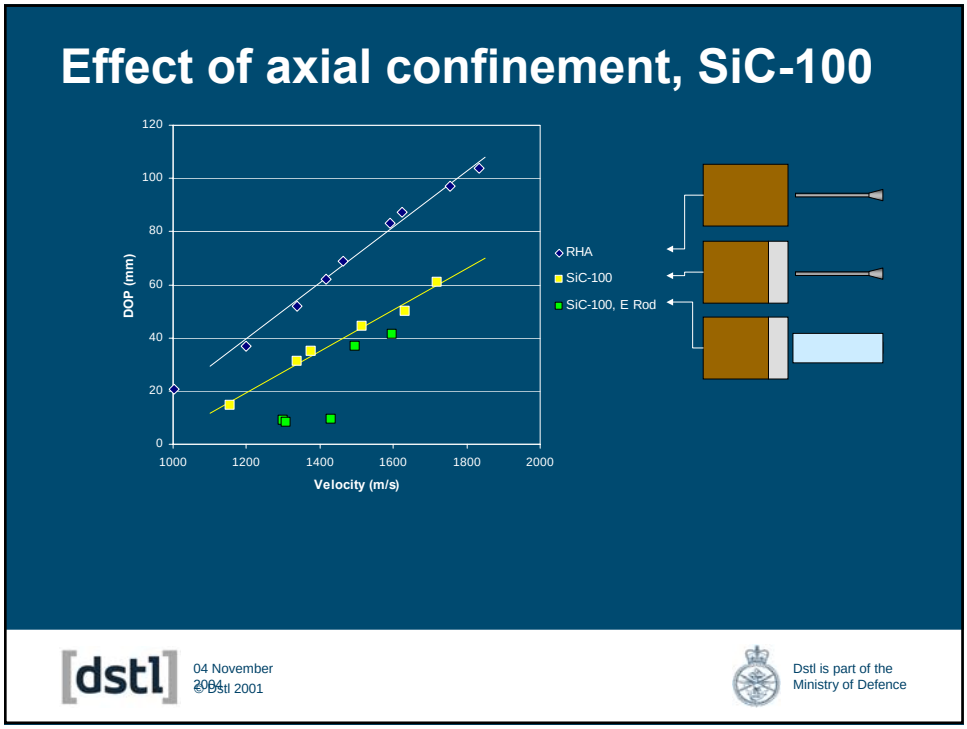
Effect of axial confinement, SiC-100
DOP (mm)
Velocity (m/s)
RHA
SiC-100
SiC-100, E Rod
04 November 2004
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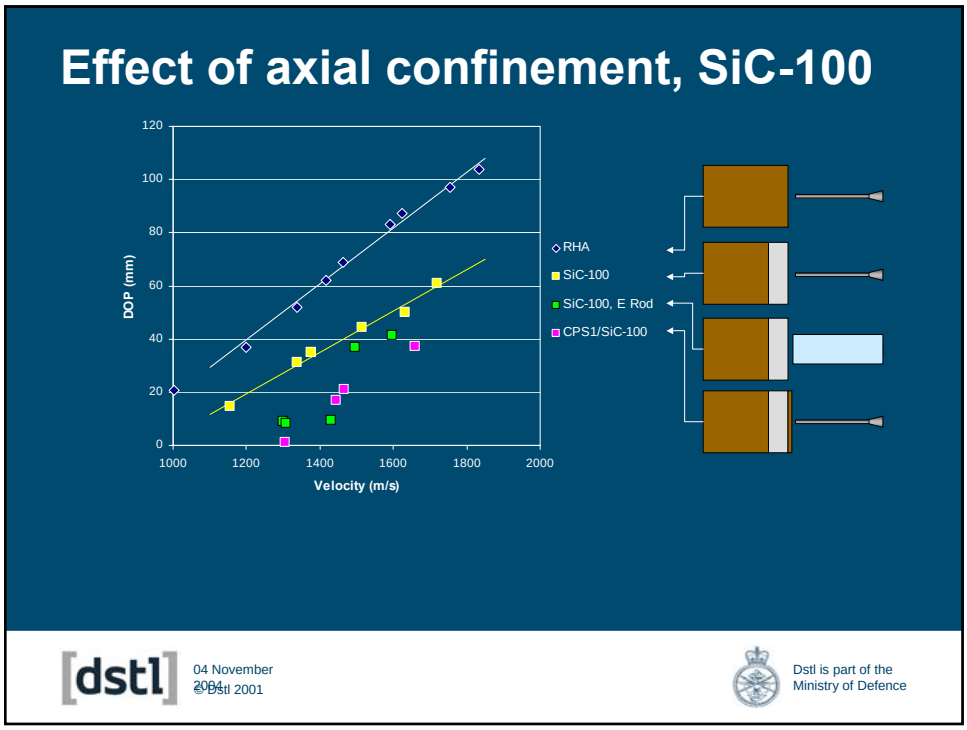
Effect of axial confinement, SiC-100
DOP (mm)
Velocity (m/s)
RHA
SiC-100
SiC-100, E Rod
CPS1/SiC-100
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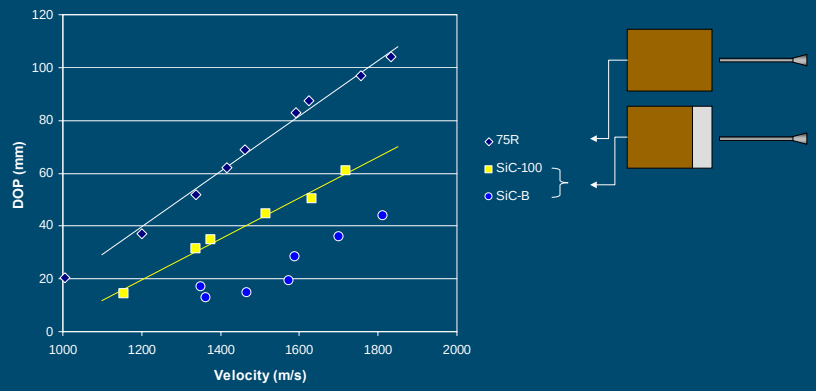
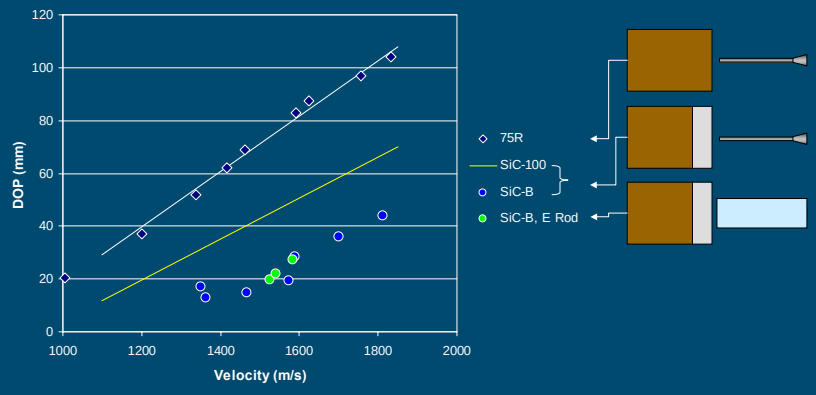
Notes

Effect of axial confinement, SiC-B



- Comment

Effect of axial confinement, SiC-B



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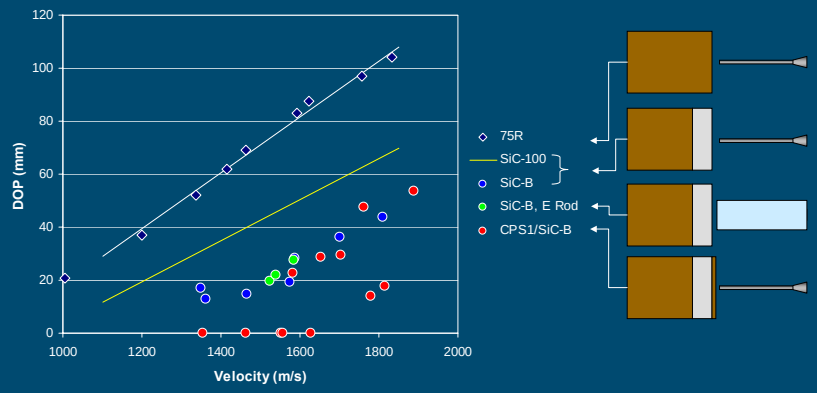
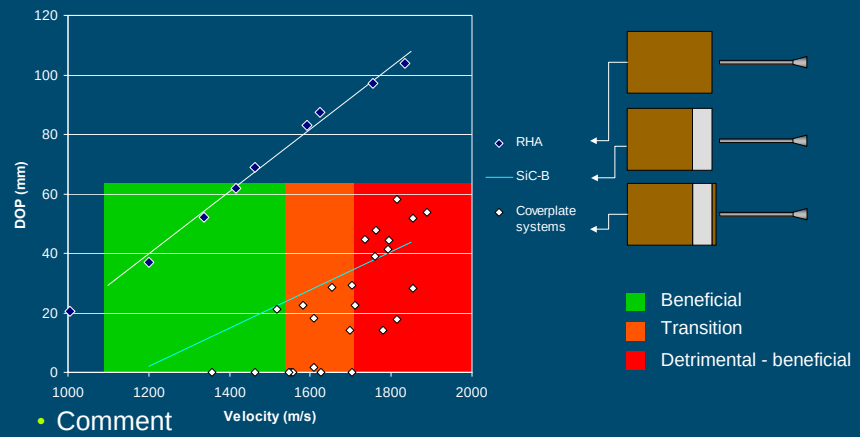
Effect of axial confinement, SiC-B



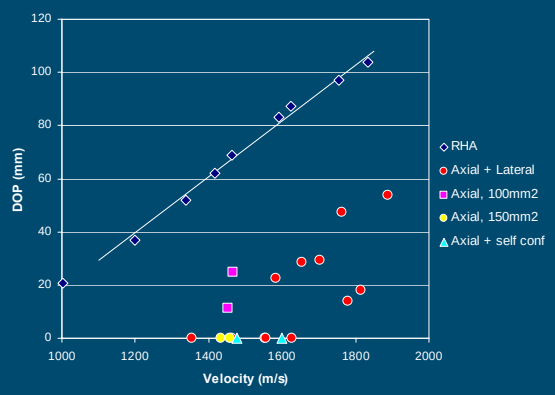
- Coverplates yield significant benefits at ordnance velocity

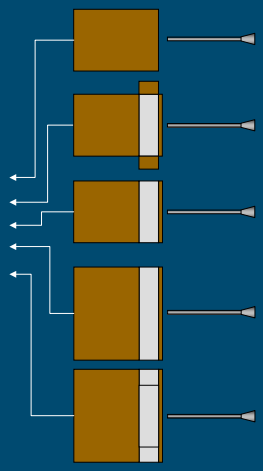
Effect of coverplates - SiC-B



- Comment

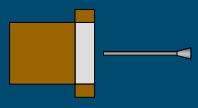
Lateral Confinement

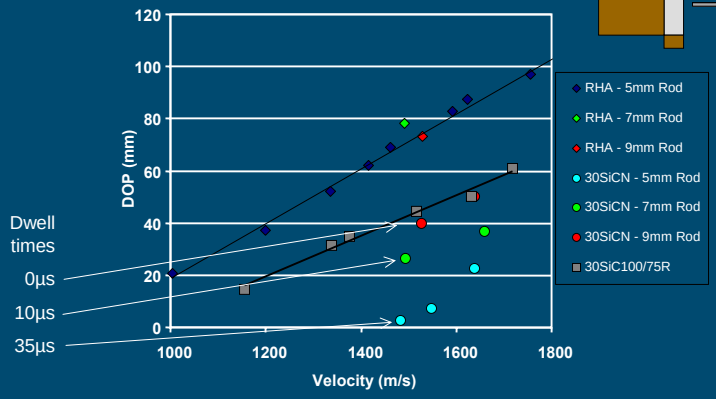




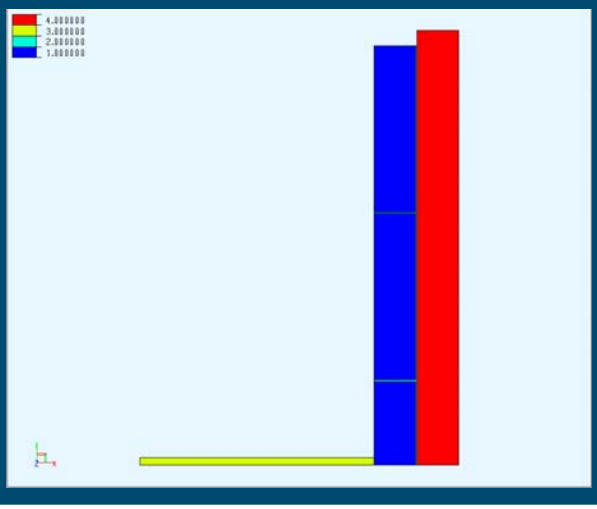
- Removing lateral confinement significantly reduces performance
- Increasing lateral dimensions restores performance
- Self confinement: 100 x 100mm tiled array of glued neighbours

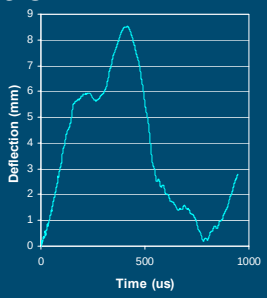
Scaling of rod calibre on dwell





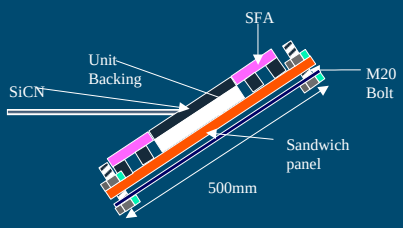
Analysis of finite targets
ELFEN numerical simulation

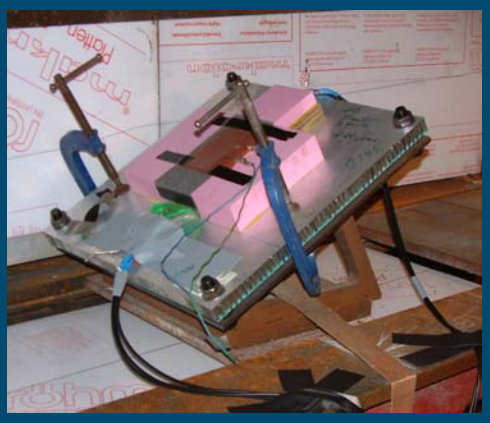




- Peak back plate deflection 8.5mm

Instrumented, finite backed target





Ballistic analysis and modelling of ceramic armour subject to KE threat

- Task 1:- Quantify scaling effects on dwell
  - Rod diameter effect on semi-infinite backing
  - Quantification of Lateral confinement
  - lateral extent
    - Magnitude of confinement (mechanical and strain rate)
  - Quantification of relative backing stiffness and stress transmission.
    - Thickness, transmission boundary (axial), impedance.
    - Instrumented targets

Ballistic analysis and modelling of ceramic armour subject to KE threat

- Quantify rod scaling effects on dwell (5, 7 and 9 mm Φ)
  - Coverplate effects (including axial force)
  - Obliquity.

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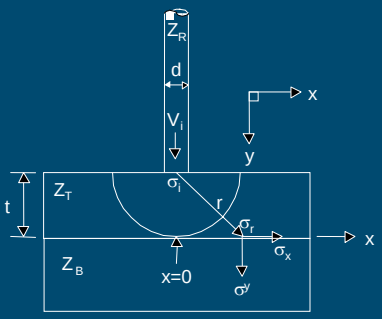
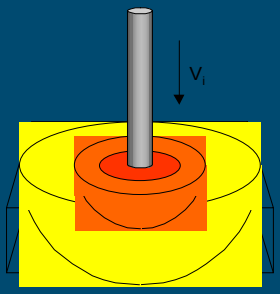
Task 2:Analytical modelling parameters

- Review analytical models
- Develop analytical/empirical dwell model
  - Effectively produce a design guide for ceramic dwell





Improved material modelling methods for ceramics

- The dwell phenomenon in non-oxide ceramic interaction with long rods is an essential aspect of performance.

- It is imperative to model well the duration of dwell followed by a period of steady penetration. It is not acceptable to ‘optimise’ numerical parameters to give a correct final DoP or average penetration rates.

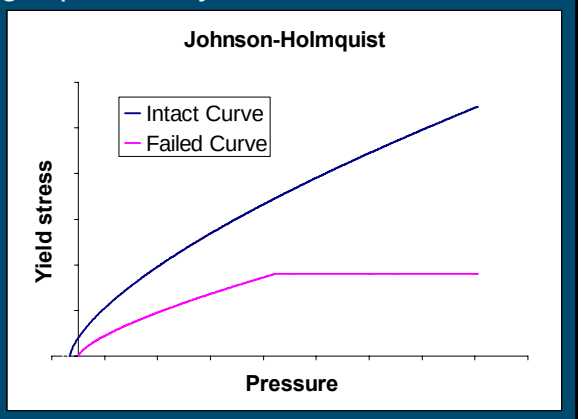
Remeshing applied to ceramics

Ceramic dwell modelling is particularly sensitive to erosion

- Deviatoric strength is pressure dependent.
- Erosion artificially releases the hydrostatic pressure at the interaction zone and reduces the yield strength.

$$D = \sum e_p / e_p^{\,f}$$

$$e_p^f = D1(P^* + T^*)^{D2}$$

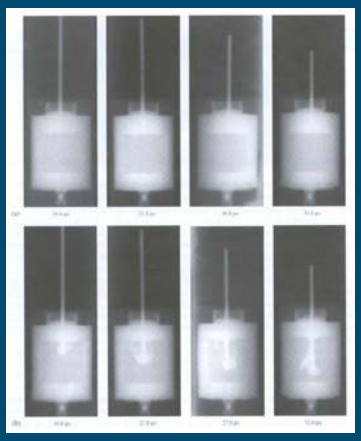


Improved material modelling methods for ceramics

- Dstl have been working with Rockfield to develop improved ceramic failure models and numerical techniques to model dwell and its termination.
- Adopted Holmquist's approach:
  - revert to JH1 w.r.t. damage model to switch intact to failed surface instantaneously
  - prevent pressure oscillations normally introduced by erosion using adaptive remeshing - DAMO
- Modified the method of damage accumulation
- Benchmarked against published experimental data

Notes

Benchmarked against Lundberg's experiments



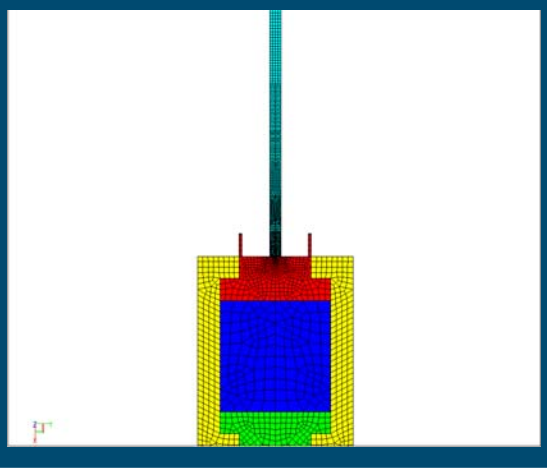
- Reverse ballistic impacts of encapsulated ceramic targets were studied.
- Three performance regimes were noted
  - Complete interface defeat
  - Steady state penetration
  - Partial interface defeat followed by s.s. penetration
- Any ceramic model must reflect these regimes.

P. Lundberg *et al*, Int. J. Imp. Eng. 2000, v24 p259

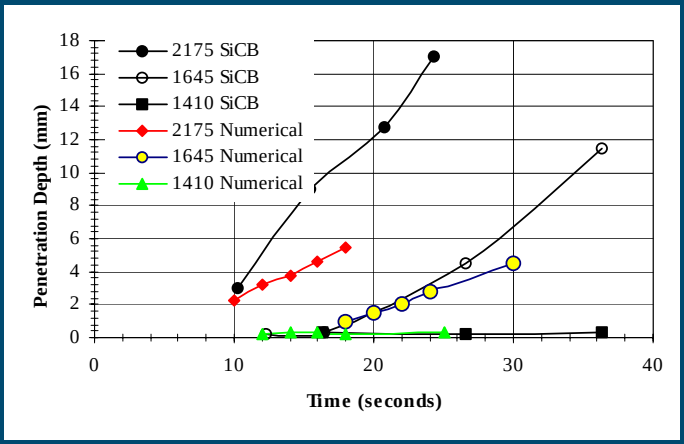
Modelling reverse ballistics

With JH1 model in ELFEN demonstrated simulation of:

- Complete interface defeat
  - v_i=1410 ms^{-1}
- Steady state penetration
  - v_i=2175 ms^{-1}
- Partial interface defeat followed by steady state penetration
  - v_i=1645 ms^{-1}



Summary of the Lundberg benchmarking trials



Ceramic material modelling

- Complete dwell and partial dwell can be modelled using the JH1 model and by using adaptive remeshing
- Dwell periods match experimental reasonably well but the penetration rates are not so well reflected
  - This is due to the damage accumulation profile affecting the numerical materials ability to ‘flow away from the penetrator’
  - this is in part a consequence of the mapping operators ability to re-map field variables and in part due to the algorithm used for accumulating damage

Ceramic material modelling

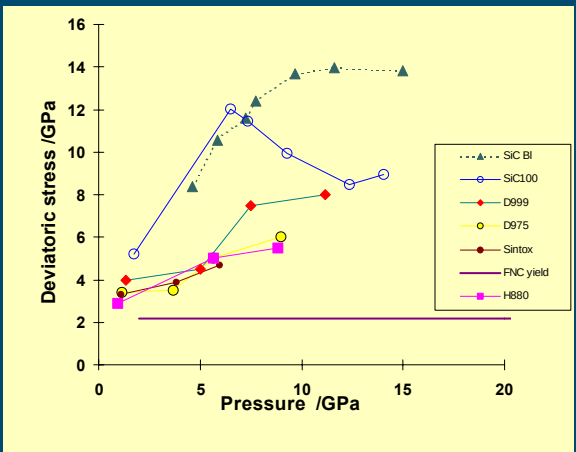
- Modification of damage accumulation algorithms
- Calibration of aspects of the ballistic programme
  - coverplates
  - different materials
  - obliquity

Ballistic analysis and modelling of ceramic armour subject to KE threat

- Programme duration 3 years
- Equitable workshare
  - 15-20 ballistic shots /establishment year
  - modelling
- Estimated cost ~ 60 K Euros /year

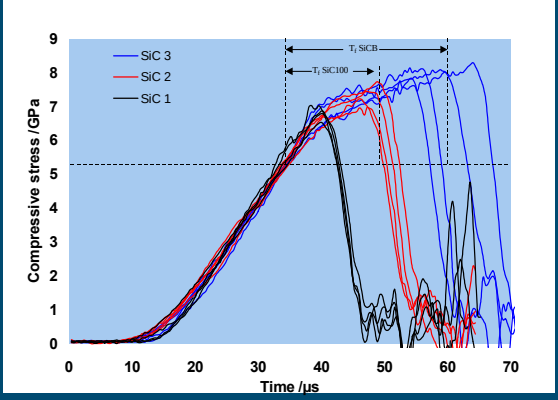
END

Deviatoric strength of ceramics
Why we use ceramics



Damage kinetics: SiC100 and SiCB

SHPB strain rate ~1000/s



1 = AME
2 = SiC100
3 = SICB

Characteristic Failure Times:

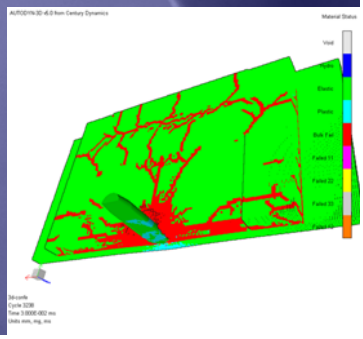
AME = 12µs
SiC100 = 20µs
SiCB = 30µs

F.5 Ceramic protection – Martin van der Voorde

The use of finite element simulation

Ceramic Protection

TNO Prins Maurits Laboratory



Scope

- **The use of finite element simulations (Autodyn)**
- **Examples**
- **The effect of parameter change**
- **Proposal**

Finite elements simulations (Autodyn)

- In order to qualify armour materials and/or concepts
- In order to visualize and understand occurring …

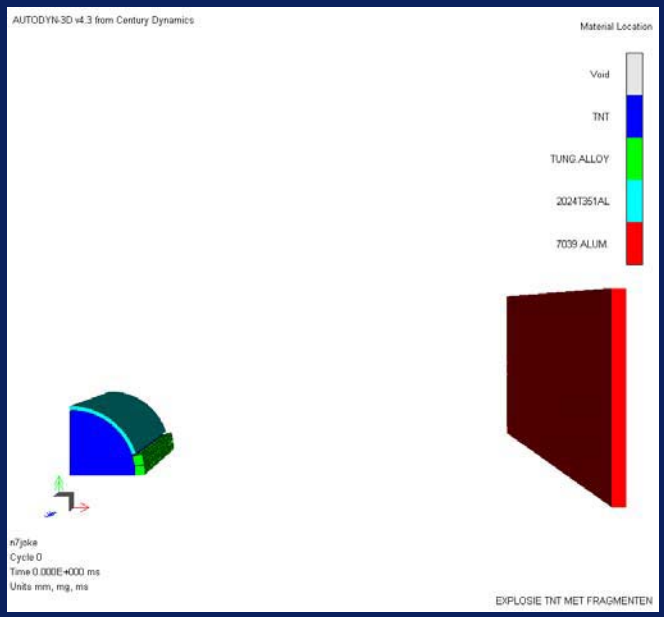
… effects and mechanisms

Examples of finite element simulations (Autodyn)

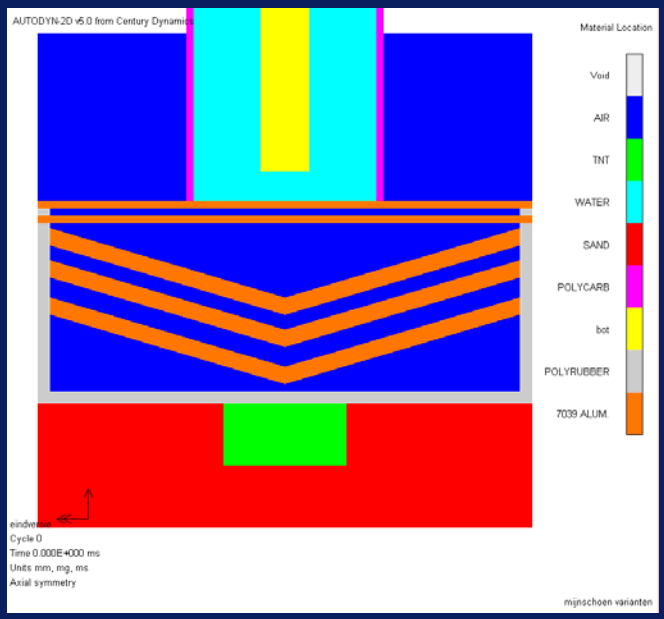
- **Penetrative capacity of preformed fragments**
- **Decreasing the effect of AP-mines**
- **Blast-wave interaction**

- **Projectile-target interaction in armour concepts :**
  - Various projectiles:
    - Small caliber: 7.62 AP; 12.7 API; 14.5 API-B32
    - Medium caliber: 25 mm APDS
    - Fragment Simulation Projectile (FSP)
    - Long rods
  - Various armour materials:
    - Brittle armour (ceramics, high hardness steel)
    - Ductile armour (Al-alloys, Ti-alloys, Mg-alloys)
    - Composite armour (Dyneema-UD)
    - Woven material
    - Concepts (combined, obliquity, …)

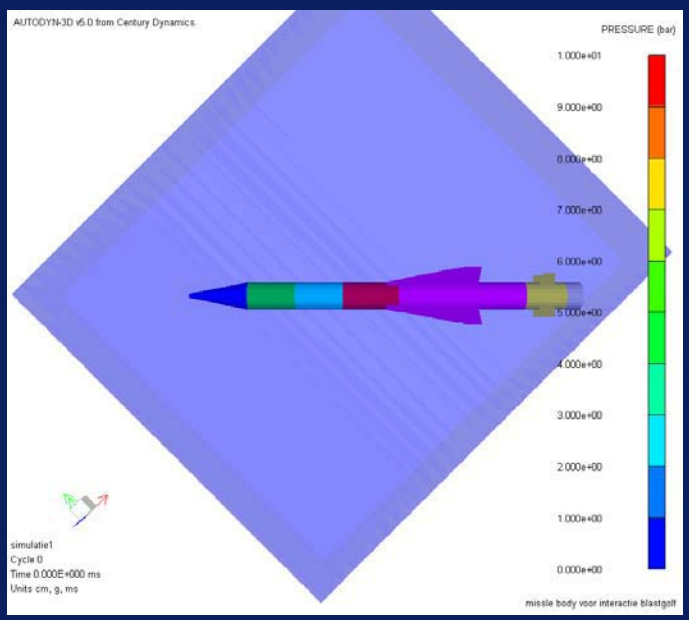
Penetrative capacity of preformed fragments



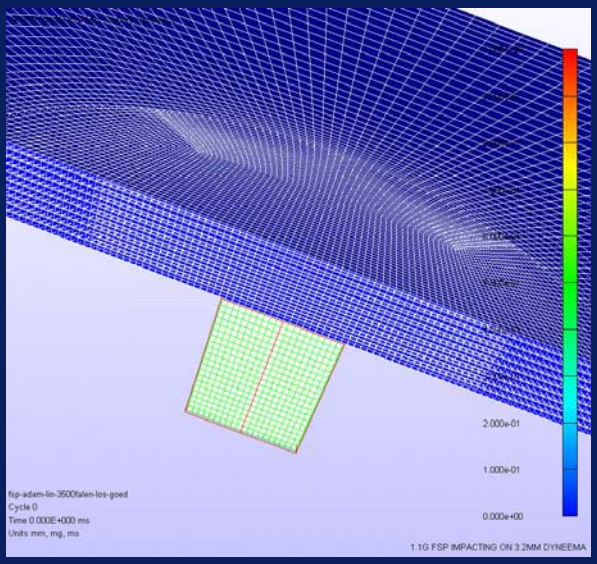
Decreasing the effect of AP mine

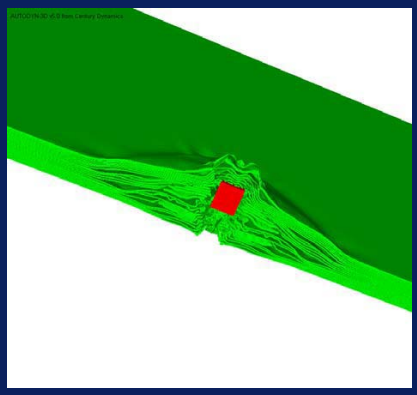


Blast-wave interaction

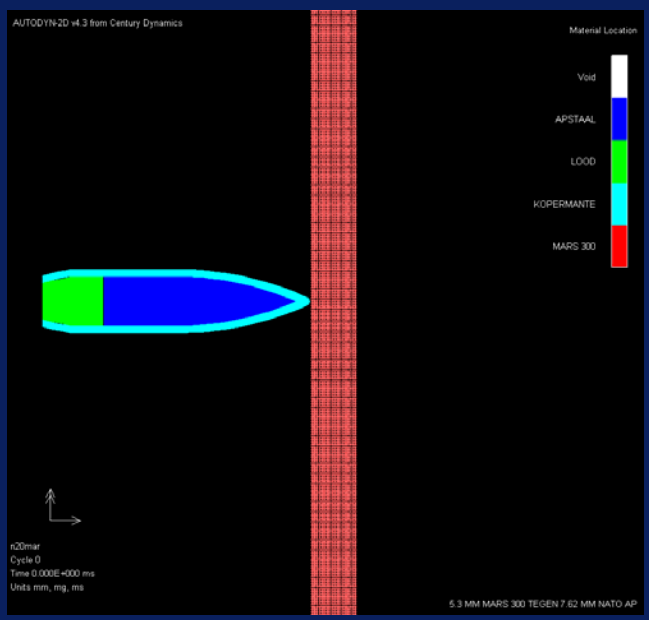


Projectile-target interaction
Composite target with FSP – 1.1 gram

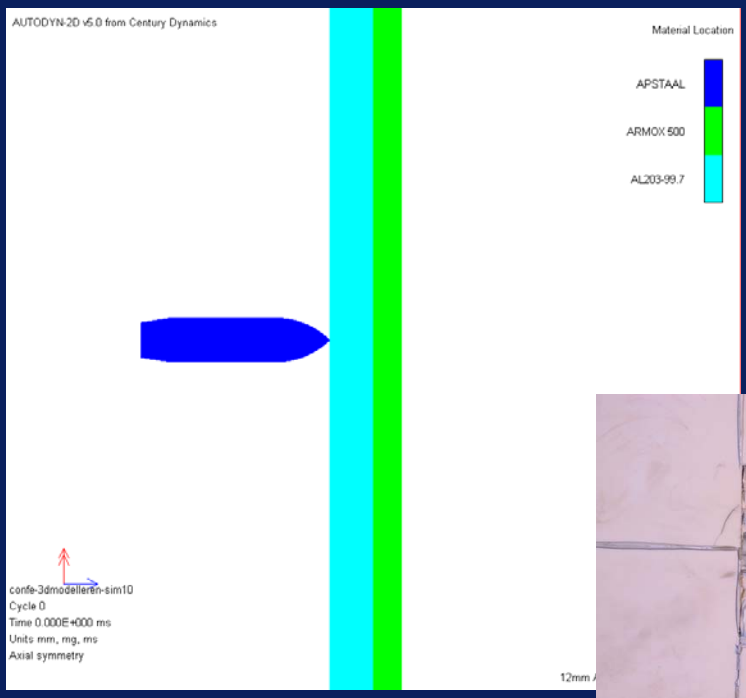




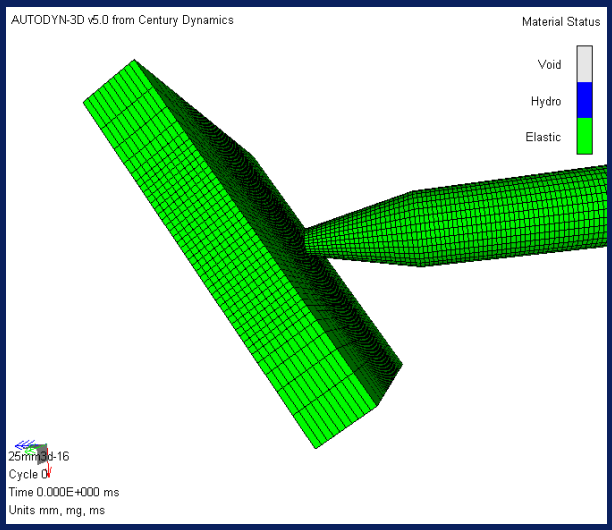
7.62 mm AP NATO vs. High hardness Steel



14.5 mm API B-32 vs. Ceramic (Al_2O_3) + steel

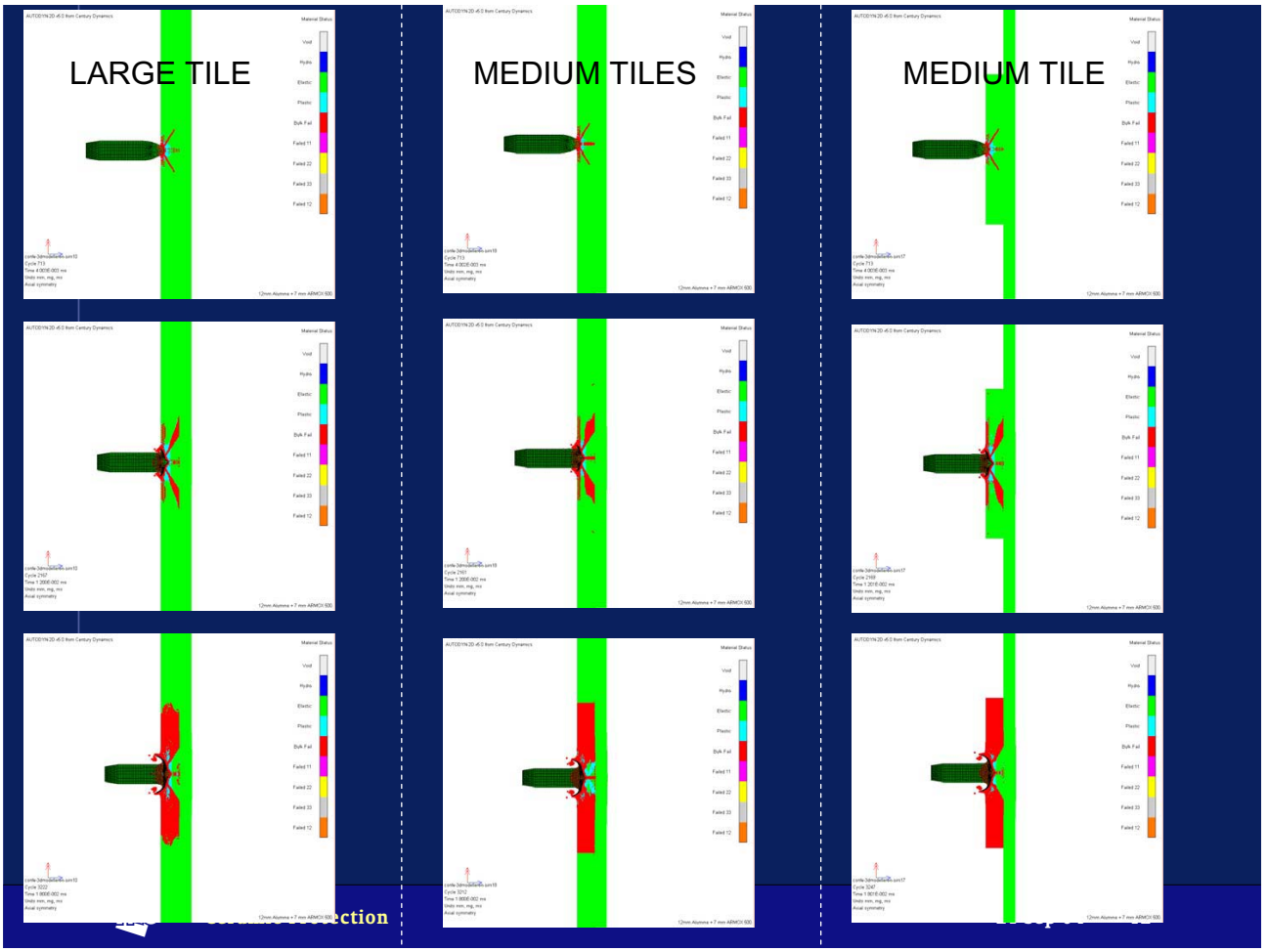


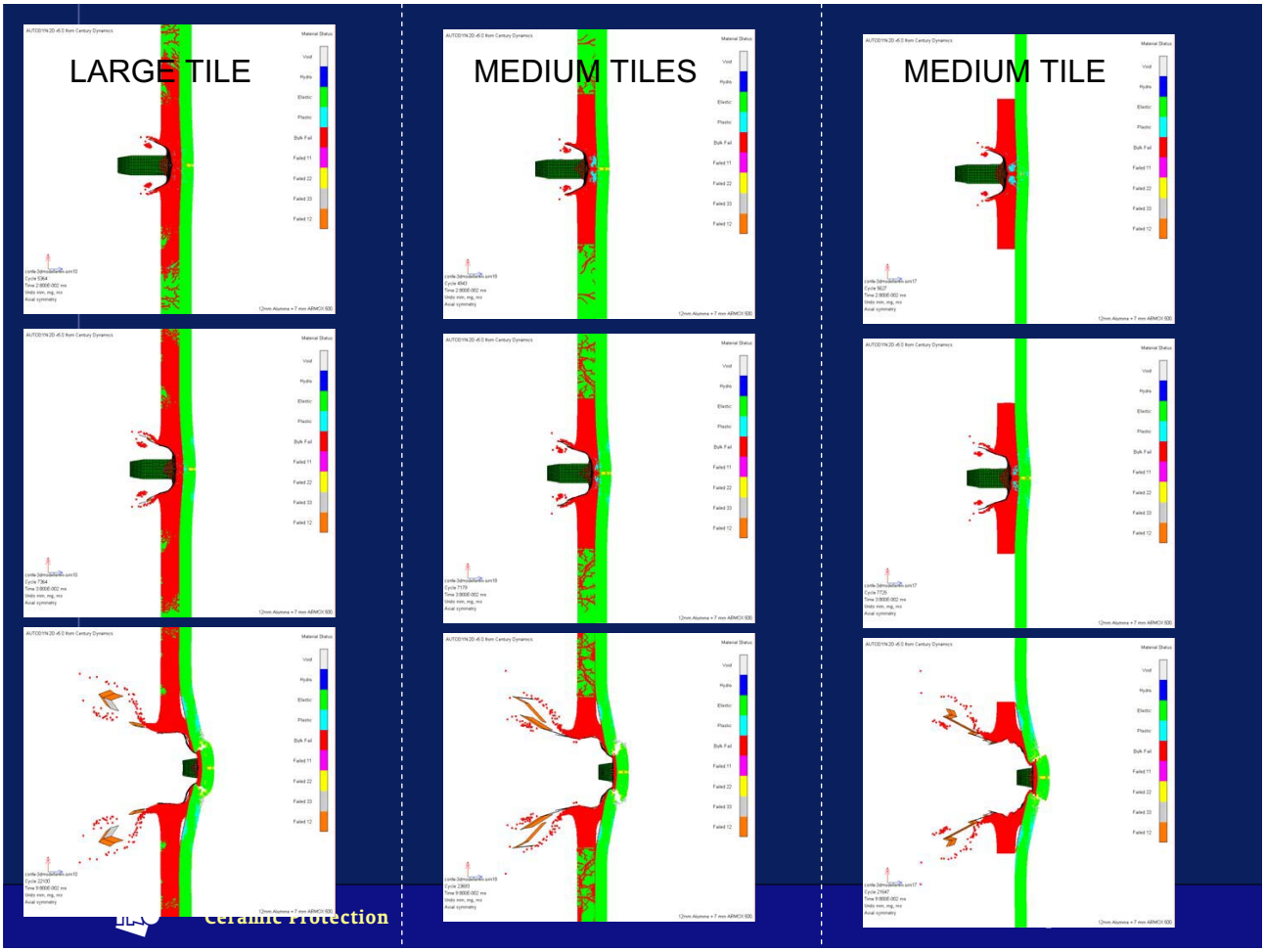
Armour concept (EM launch)



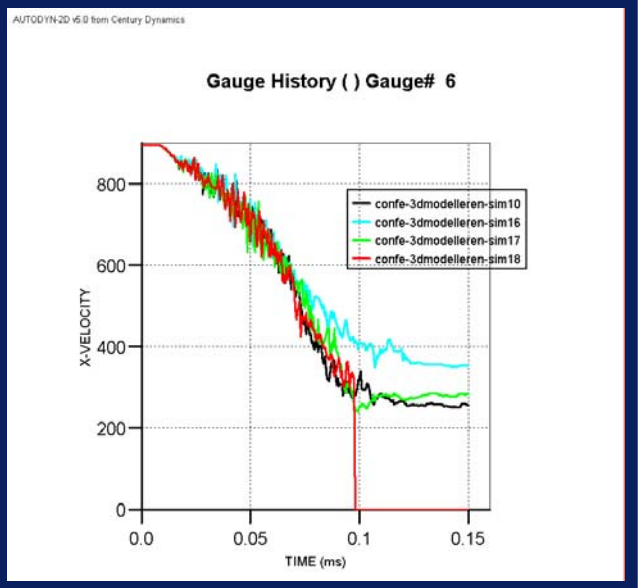
Parameters change

- Target thickness
- Target material
- Target size
- Impact velocity
- Projectile type
- …
- …





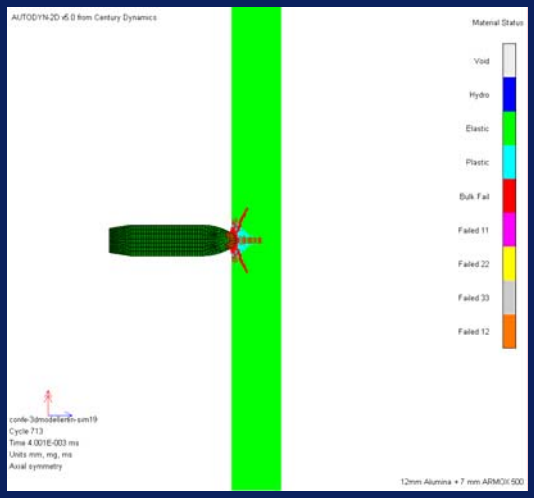
The effect of the size of a tile



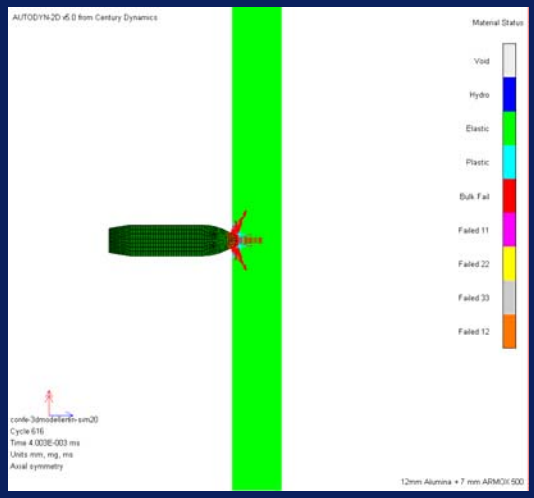
	Tile (cm)	V (m/s)
Sim10	1 large (20)	895
Sim16	1 small (2)	895
Sim17	1 medium (10)	895
Sim18	2 medium (3 x 10)	895

Impact with two different speeds

V = 895 m/s

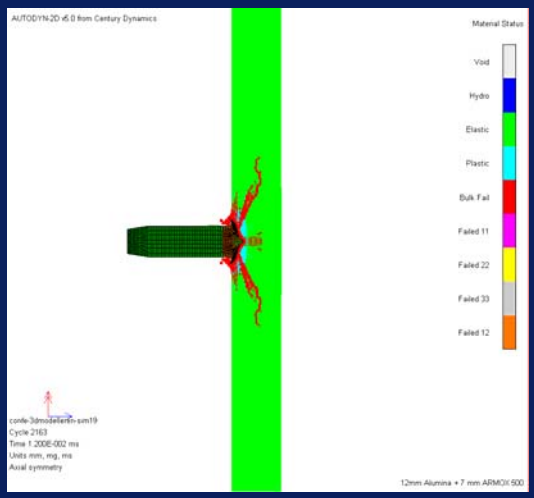


V = 772 m/s

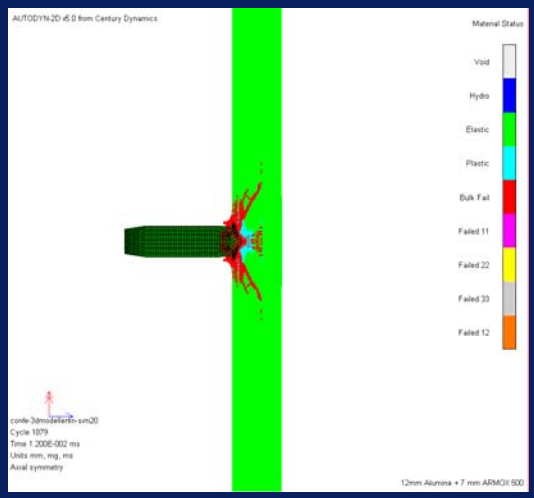


Impact with two different speeds

V = 895 m/s

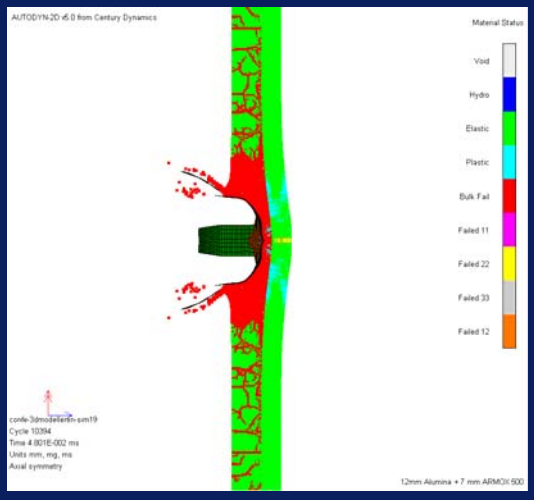


V = 772 m/s

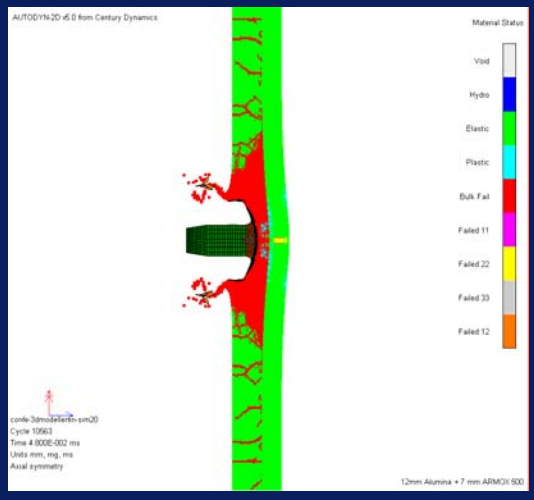


Impact with two different speeds

V = 895 m/s

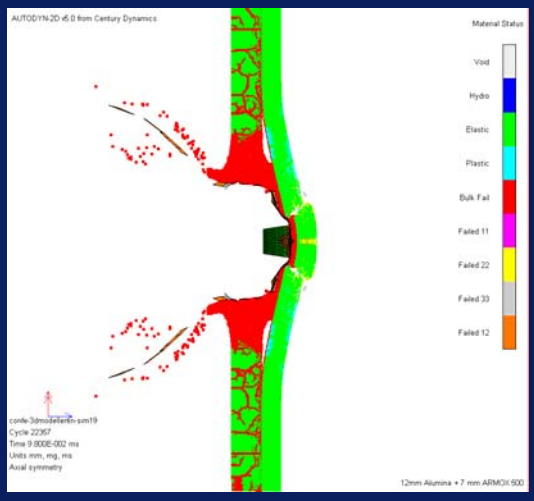


V = 772 m/s

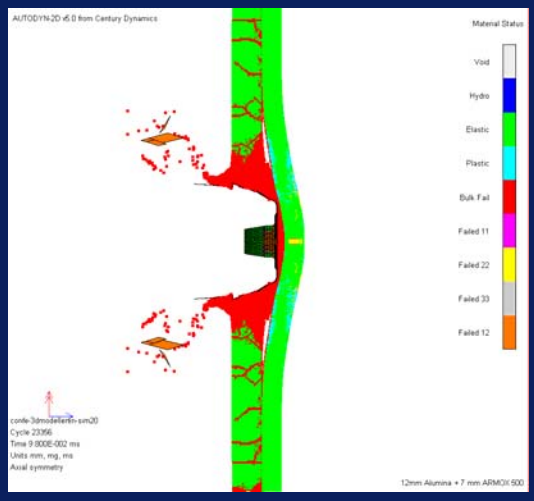


Impact with two different speeds

V = 895 m/s

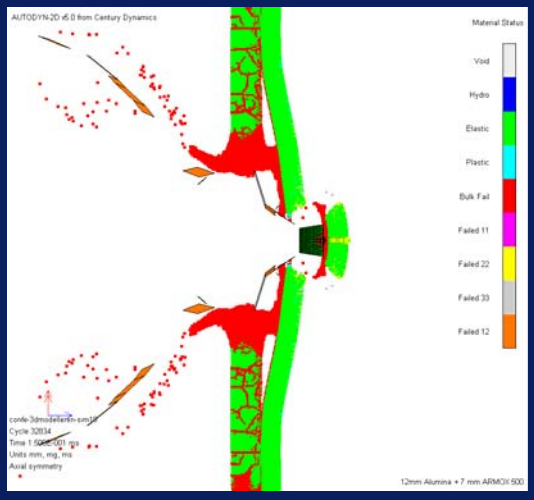


V = 772 m/s

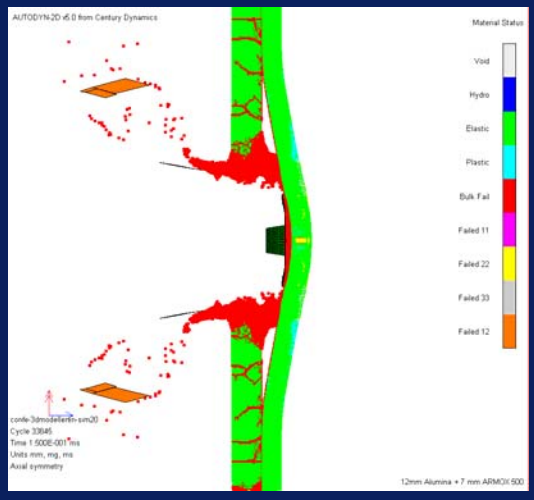


Impact with two different speeds

V = 895 m/s



V = 772 m/s

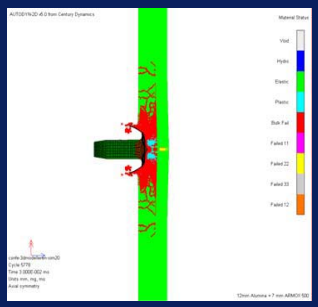


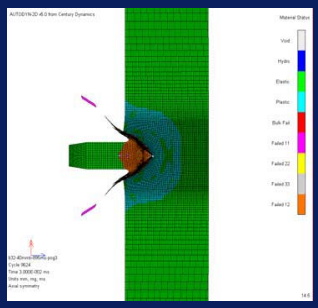
Difficulties with projectile

B32 vs ceramic: good model

Same B32 model

B32 vs Ti: wrong model

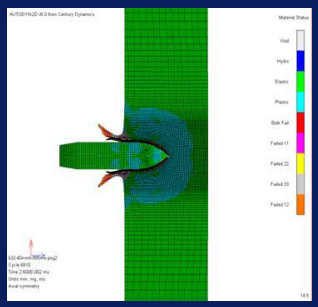


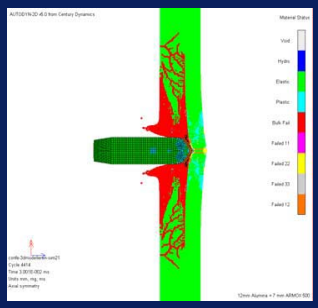


B32 vs Ti: good model

Same B32 model

B32 vs ceramic: wrong model





Difficulties with projectile

- Different models for the same projectile for different targets

- **Literature survey: the solution ?**

Examples Literature

- 21st IBS, Adelaide, Australia, 2004: "Anomalous target failure at small angles of obliquity"

tests.

To model the bullet (see Fig 3), data was used from the AUTODYN material libraries. For the tip, the constitutive relationships for S7 steel were used; the yield strength was increased to 1600MPa to represent the higher hardness of the steel tip compared to S7 tool steel. A failure strain of 55% was implemented to model the erosion of the tip during penetration. Lead antimony and copper were used to model the lead core and the gilding jacket respectively – again the constitutive relationships for these materials were available in the AUTODYN™ material libraries. The discretised target and bullet consisted of 79236 and 9030 nodes respectively.

For each of the target plates with the different yield characteristics, three different

- 54th ARA Meeting, Santa Fe, New Mexico, 2003: "Ballistic impact on ceramic tiles. Experimental and numerical analyses"

of 150 GPa, a specific heat of 880 J/KgºK and a temperature of reference of 300K. The material model for the projectile was a combination of a linear equation of state and a strength model of Johnson-Cook [8], because of its proved behavior for steels.

Difficulties with projectile

- In reality: different models for the same projectile for different targets
- In literature 'tuning' of materials from Autodyn library
- Very few material properties for projectiles can be found

- Ideal situation: One model for each projectile

- no subject in fundamental research with long rods

Proposal for collaborative program

'Characterization of core material'

- Dynamic material characterization
  - Flyer plate experiments with VISAR
  - Taylor experiments (with VISAR)
  - Hopkinson bar experiments
  - Comparative Impact experiments (diagnostic)
- Static material characterization
  - CEM
  - Tensile testing
  - Fracture toughness

F.6 Penetration of tungsten carbid into steel targets - John Moxnes

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Penetration of Tungsten Carbide into Steel Targets

John F. Moxnes, NDRE, Norway
Eva Friis, Nammo Raufoss AS, Norway

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Introduction

Purpose:

- To show that the simulated penetration capability of a typical Tungsten Carbide penetrator is depended on the numerical solver.

Topics:

- Numerical study of the penetrator-target interaction
- Establishment of material data
- Simulation and comparison with firing experiments

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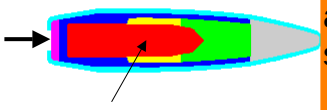
Tungsten Carbide Penetrator in 12.7 mm MP

Inert 12.7 mm MP ammunition



Tungsten Carbide penetrator

Target: 22 mm armour steel

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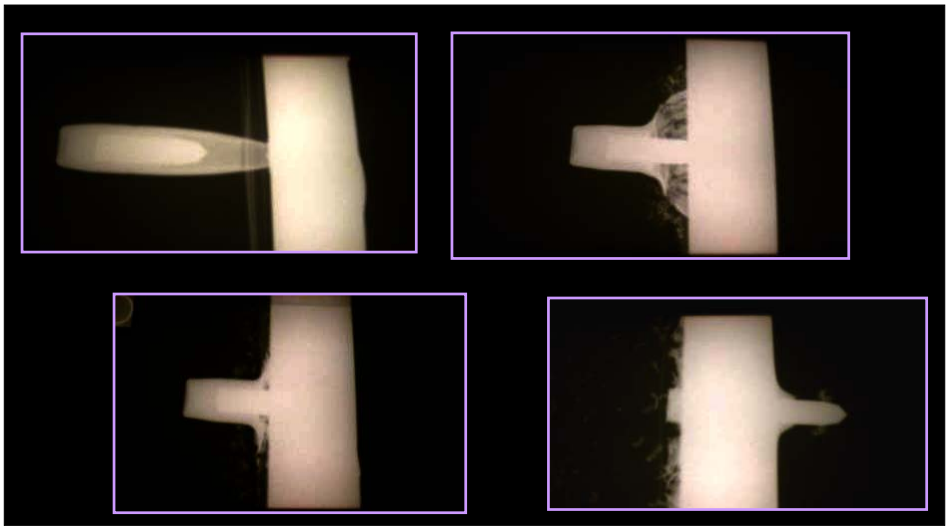
Flash X-Ray Pictures



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Penetrator-Target Interaction

- Numerical study of the stresses in the penetrator at impact velocities of 800 – 1000 m/s:

- Compared results from various numerical solvers:

Penetrator	Target	Code
Lagrange	Lagrange	Autodyn 2D
Lagrange	Lagrange	HI Dyna 2D
Lagrange	Euler	Autodyn 2D
Lagrange	Virtual Target	Autodyn 3D
SPH	SPH	Autodyn 2D

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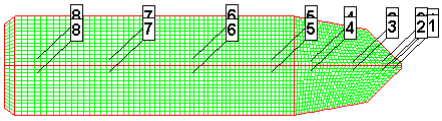
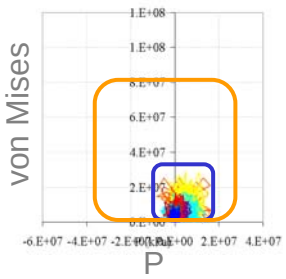
Stress Plots



= HI Dyna

= Autodyn



Lagrange

- v_0=820 m/s

- For this simulation we choose a superficially high fracture/yield surface to track the high stress levels (elastic projectile)

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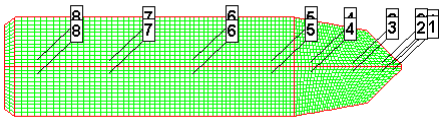
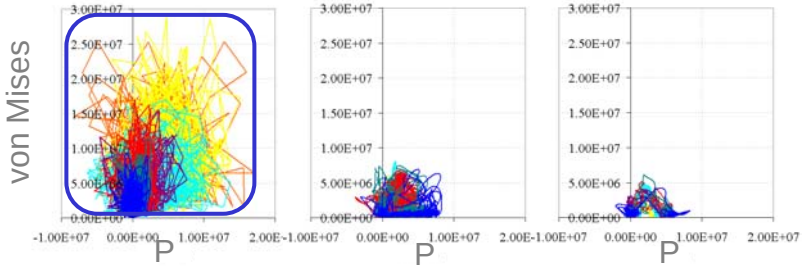
Stress Plots



- v_0=820 m/s



Lagrange (Autodyn) | Euler | Virtual Target

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The Virtual Target

- For the ”Virtual Target” approach, the target is not modeled explicitly in Autodyn
  - the stresses are calculated from analytical cavity expansion theory in a user subroutine
  - the stresses are applied to the projectile through boundary conditions on the surface

$$\sigma_r = \frac{3}{2}\rho_t u^2 + \frac{2}{3}Y_t\left(1 + Log[E_t / 3(1-\nu_t)Y_t]\right)$$

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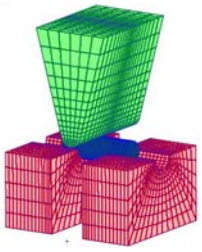
Establishment of Material Data

Bending **Compression**



Marc 3D Simulation:

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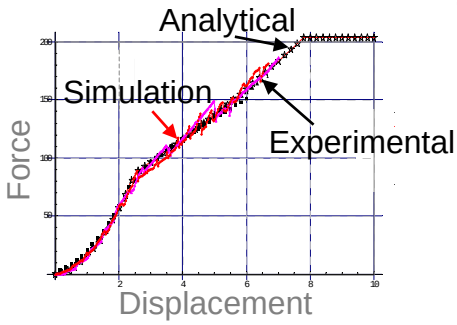
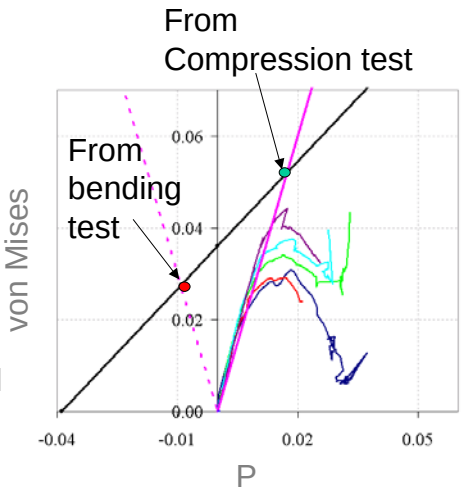
Indentation Test





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Material model for simulations

- The established yield/fracture surface was fitted into the Johnson-Holmquist damage model, which we used for simulation of the firing experiments.

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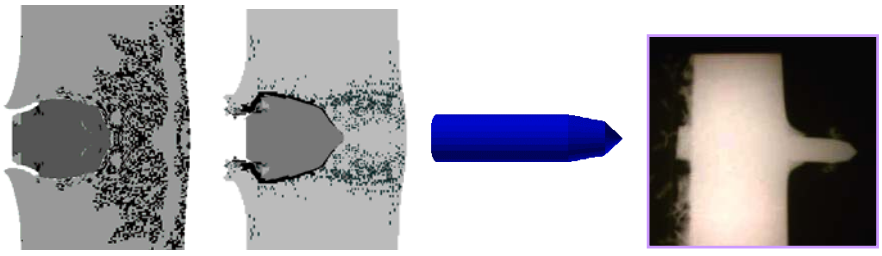
Simulations of Firing Experiments
v_0=820 m/s, Fixed Material Model



Lagrange Euler Virtual Target Experiment

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Conclusions

- In the dynamic situation the numerical methods all give different levels of stress in the penetrator.
  - the stresses in the Lagrange-Lagrange approach appear to be unphysically high
  - the virtual target solver gives results closer to experiments than the Eulerian solver
- The Johnson-Holmquist Damage Model appears to be suitable for modeling the fracturing of Tungsten Carbide, although plasticity is not accounted for in the simulations.

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F.7 Methods for simplifying penetration calculations with hydrocodes – Jan Teland

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Methods for simplifying 3D-penetration simulations with hydrocodes

Jan Arild Teland

Introduction

- Full hydrocode penetration simulations in 3D are very time consuming, even with powerful computers and parallell schemes.
- As a result, it can be difficult to perform sensitivity studies on the effect of changing various input parameters.
- A method for obtaining results in a shorter time would therefore be very much desirable.

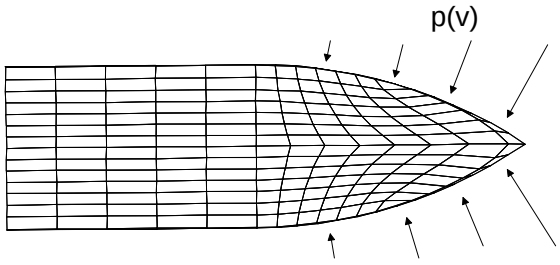
Problem

- The main problem is the enormous number of elements required to model a large target in Autodyn and similar codes.
- By using various smart modelling techniques, this number can be considerably reduced, but it will still be too large for parameter studies.
- We solve this problem by not modelling the target explicitly at all! Only the projectile is modelled in the normal way.
- The target-projectile interaction will then be taken care of through implementation of a user subroutine.

Implementing target behaviour

- User subroutines enable us to access the internal physical variables during the simulation.
- From analytical theory, the stress on each projectile element can be calculated as a function of velocity (and virtual target parameters).
- By implementing this analytical force on the projectile through a (user defined) boundary condition, the projectile will behave in (roughly) the same way as inside a real target.

Implementing target behaviour



p(v) is calculated from CET. It is a function of the projectile velocity *v* and (virtual) target properties.

Validity range

- The validity of the new approach will depend on how good an approximation of reality is given by the analytical theory implemented.
- In the current approach, an analytical penetration model based on cavity expansion theory (CET) has been implemented.
- This theory is used in a variety of penetration models in the literature and has been seen to produce good results.
- If CET is extended/modified or a better theory is derived, the user subroutine can easily be amended to account for this.

Features of the new method

- Boundary effects are accounted for analytically. The force is smaller on projectile elements close to a target boundary.
- The reduction of the force due to boundary effects is also calculated from analytical CET.
- Currently, both cubical and cylindrical, finite and semi-infinite targets can be selected. More complex target geometries can be implemented if desired.

Virtual target input parameters

- Target geometry
  - Cylindrical (radius, length)
  - Prism (position of corners)
  - Semi-infinite
- Target material
  - Density
  - Elastic properties
  - Yield model (Mises, Mohr-Coulomb etc.)

Limitations of the new approach

- The new approach is only useful if our interest lies in what happens to the projectile.
- The approach gives no information about damage to the target, crater size etc.
- The projectile nose must not deform significantly during the penetration process. Bending of the projectile body does not seem to be a problem.

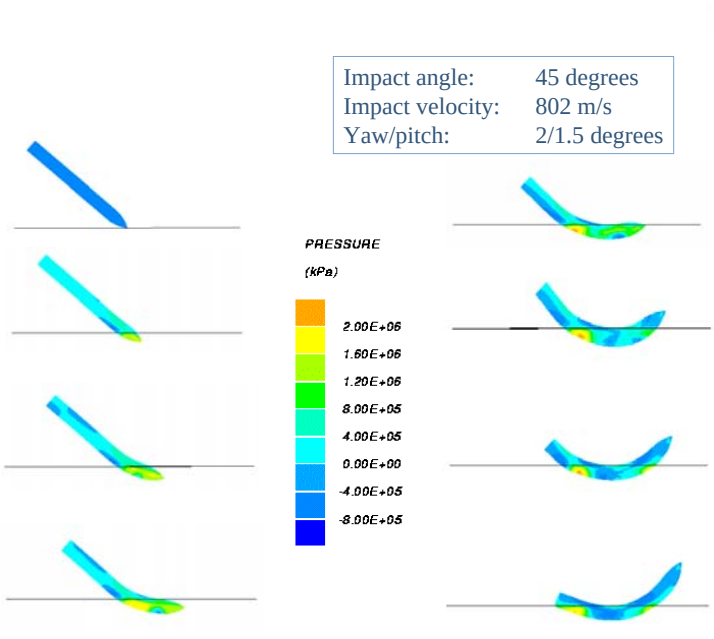
Applicability of the new method

- For a simple case of normal impact, the method gives the same results as regular analytical theory.
- The method is therefore mostly useful when it comes to *non-normal impact*, which is difficult to model adequately using analytical theory.
- Examples are:
  - yawed impact
  - oblique impact
  - combination of yawed and oblique impact etc.

Experimental verification

- The approach has been compared to experiments by Warren and Poormon (Int J Imp Eng. 2002)
- They fired steel projectiles of L=59.3 mm, l=11.8 mm, and $2a$ = 7.11 mm on aluminium targets at various velocities and angles of obliquity.

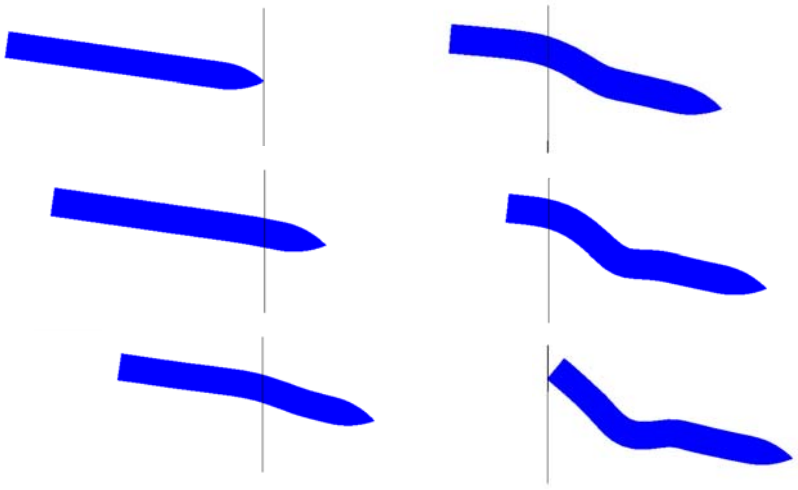
- The new method gave results that were in good agreement with the experiments.



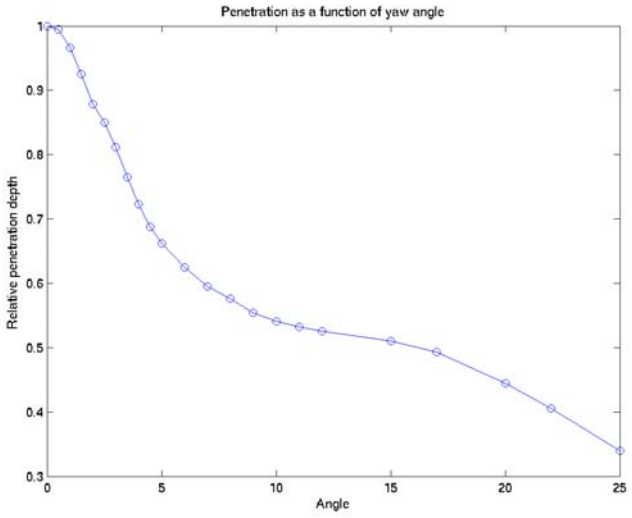
Example of use: Yawed penetration

- As an example, a sensitivity study was performed to find the relationship between yaw angle and penetration depth.
- 23 simulations were completed in a few hours, and would have taken much longer using a full 3D simulations.

Impact velocity: 1000 m/s
Yaw angle: 10 degrees



Penetration depth as a function of yaw angle



F.8 Protection of soft skin vehicles – Ove Dullum

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Protection of light vehicles

Ove Dullum

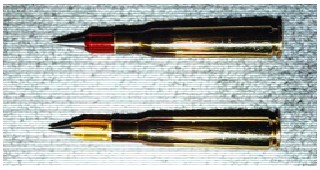
Div. Protection

Possible roles for light vehicle

- Fast patrol vehicle
- Law enforcement units
- Ambulances
- NGO relief help, emergency and rescue teams
- Civilian acquired vehicles

The threat

- Hand guns (pistols, revolvers)
- Rifles (5.45 – 7.62 mm)
- Machine guns (12.7 – 14.5 mm)
- Hand grenades
- Land mines (anti-personnel)
- Light missiles (RPG-7)
- Improvised explosive devices



Requirements for a light protected vehicle

- Must protect 360° against 7.62 mm Ball — Stanag* Level 1
- Optional protection against 7.62 mm BZ — Stanag Level 2
- Belly protection against AP mines and HG — Stanag Level 1

- A majority of the loading capacity should be retained
- Its driving performances should not suffer too much
- The vehicle should have a non-provocative look
- It should be possible to adapt the protection to the threat

*)STANAG 4569
Procedures for Evaluating the Protection Levels of Logistic and Light Armoured Vehicles for KE and artillery threats

Protection weights

Ammo	Velocity	Steel thickness	Area weight steel	Area weight state-of the-art
NATO Ball	830 m/s	7 mm	55 kg/m^2	25 kg/m^2 (15 kg/m^2)*
NATO AP	805 m/s	15 mm	120 kg/m^2	38 kg/m^2
Bofors WC	880 m/s	25 mm	200 kg/m^2	48 kg/m^2

* Value is claimed but not verified

Toyota Landcruiser 105

Toyota Landcruiser

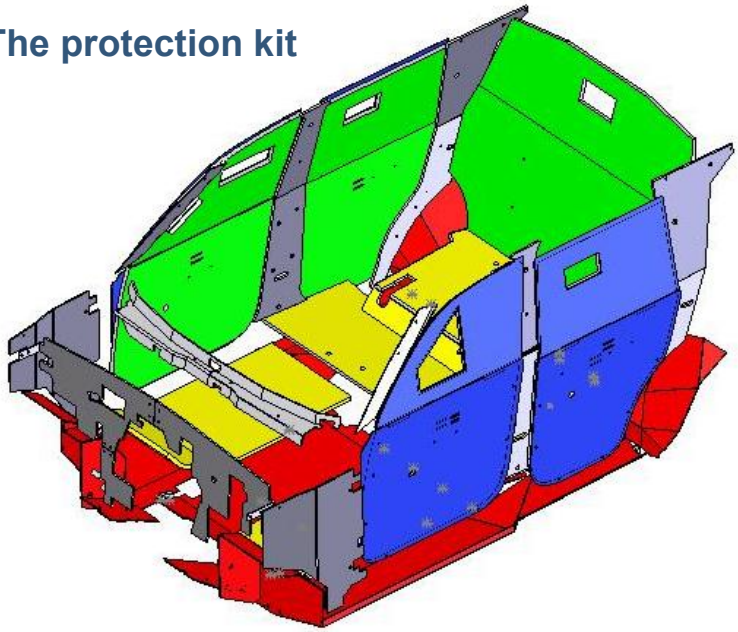
- On loan from the DCDEP (Directorate for Civil Defence and Emergency Planning)
- Kerb weight : 2250 kg
- Payload: 910 kg (minus winch, roof rack, heavy bumpers, comm. equipment etc.)

Weight of proposed protection

Front doors	68 kg
Back doors	61 kg
Rear wall	35 kg
Columns	59 kg
Front	6 kg (incomplete)
Engine room wall	14 kg
Forward leg space	11 kg
Floor mats	48 kg
External mine kit	160 kg

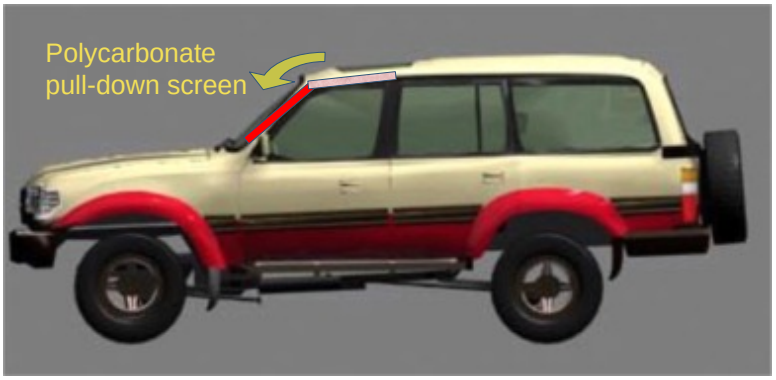
Total weight 462 kg

The protection kit



The windshield – a problem

- The windshield can not be tinted
- A 35 mm glass/polycarbonate laminate may be used
- A thick glass may make the driver sick



The Toyota Landcruiser

- Work is ongoing
- Demonstration with mock-up for potential users in October.
- In case of positive response, a real protection package may be acquired
- The possibility of upgrading brakes, suspension etc. in order to regain payload will be investigated

Fighting vehicles AT mine kit

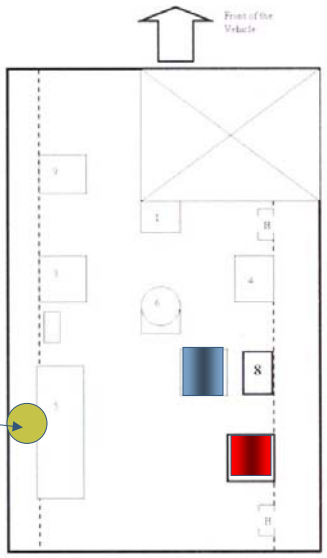
M113 **CV9030**

Testing of chairs in M113

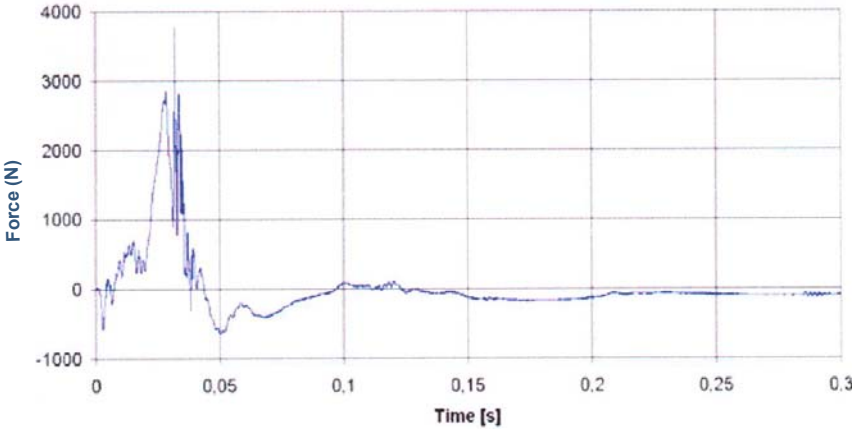
Force measurements of

- **neck,**
- **lumbar spine**
- **fibula**

5 kg TNT
AT-mine
under 5th wheel

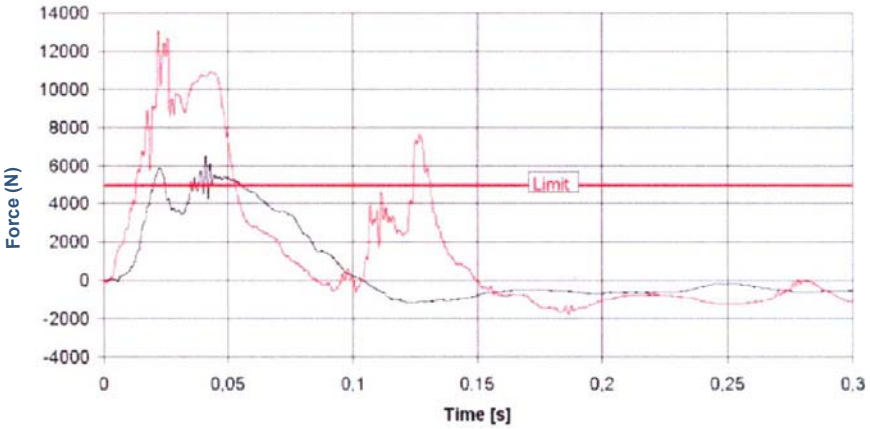


Fibula measurements



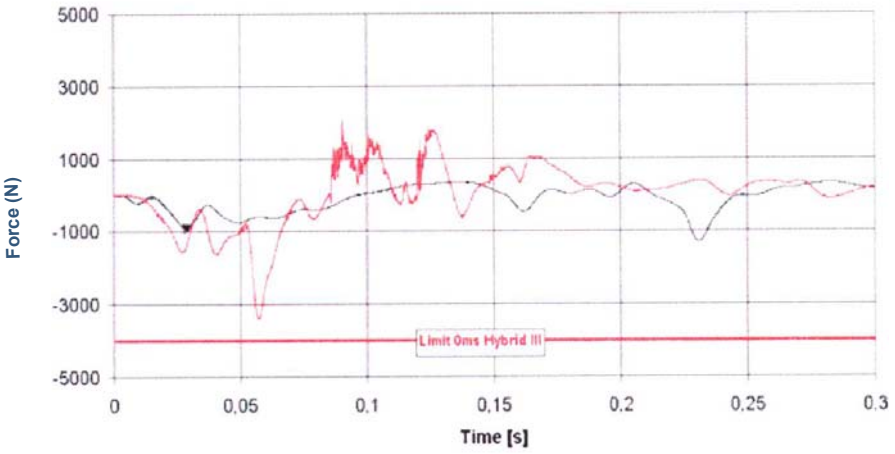
Footrest used
No injuries expected

Lumbar spine measurement



Limits exceeded in both seats

Neck measurements



Both seats passed the test

Conclusion of seat testing

The mine kit does not given complete protection
Out of 9 seat / mine combinations only 2 passed test

The lumbar spine tests are the critical ones

F.9 Explosives and munitions – Adam Cumming

ANNSC WG3
Explosives and Munitions

UK Leader - Dr Adam S Cumming

28th November 2003

ANNSC WG3

- Scope
  - Although entitled Explosives and Munitions, WG3 covers both the base technology and its application.
  - This extension has increased the level of activity, and has not, as yet caused any problems. Indeed the level of synergy has helped develop a broader awareness of technology application.
  - It is essential that this position is kept under review.

WG3 Programmes

- There were some 10 Collaborative Projects in existence at the meeting in July 2003. Some are concluding, new proposals being generated.
- One CP was combined to reflect changes amongst the participants.
- Three areas have been identified for structured Information Exchange.
- *Overall the WG is very active.*

WG3 Programme Highlights

- Continued Development of common approach to Soldier Modernisation using CAEN and other tools, after delays.
- Forward planning to jointly examine Emerging Technologies
- Development of a vertical systems aspect to the WG activities.
- *Whilst most programmes are relatively low value, they are increasingly well focussed and provide a high level of return to the participants.*

WG3 Programmes

- Areas for Structured Information Exchange:
  - Life Extension of Propellants
  - Mine Protection and MINEN Model
  - Attack of Armour
  - Performance and IM Properties
  - Missile propulsion
  - Points of contact are being identified to act as focii for these activities - some of these may be taken up within a CEPA.

WG3 Programmes

- After some slight decrease in activity, the level is rising again.
- Problems following the DERA split have been resolved and most of the issues associated with the division have been resolved.
  - Clarity in involvement essential
  - Benefit to all obvious
- Increasingly coupling both technology with applications, reflecting common strategy amongst the participants.

WG3 Links

- WG3 has close links with CEPA 14 - Energetic Materials. There are potential and actual links to other CEPAs
- Proper use of this link improves the efficiency of operation and avoids duplication of effort.
- EUROPA should assist in developing a method to deliver products irrespective of the process used.

Issues

- Possibility of covering Urban Warfare topics
  - weapon technologies NLW
  - body and vehicle models for active and passive protection
  - data exchange
- Is this an acceptable topic for WG3?

Future Strategy

- Is there overlap with CEPA 14 etc?
  - Agreed that WG3 operates within and across CEPA boundaries
  - Provides a mechanism for integrated work incorporating both technology and systems, eg soldier modernisation.
  - Offers chance to develop programmes as precursor or as development of CEPA programmes
  - Strategy must complement that of appropriate CEPAs.
- Pragmatic approach required.

Strategy 2

- Approach
  - Have annual meeting to review work in progress and look at priorities
  - Incorporate CEPA approach in this.
  - Pick up CEPA proposals for expanded action, ie in the scope, using EUROPA to incorporate valuable contributors, eg Sweden.
  - Hand ideas back to CEPAs for action, but in a coherent manner
  - Complement CEPA activities directly when appropriate, using existing good working relationships

Strategy 3

- Provide meeting place for broad based approach
  - attempt to link with procurements and demonstrators
  - review effectiveness annually
  - if value of separate existence lost, then revert to CEPA activities - not believed likely in the short term
- The Group works, and provided that this is not affected, then it will continue to develop to meet needs.
- Strategy in first draft and will remain a living document.

WG3 Strategy Conclusions

- WG3 has developed from primarily an information exchange (IE) to a group engaged in structured IE aimed at developing Collaborative Programmes (CP).
- The WG tries to operate a combination of a top down and bottom up approach to collaboration.
- Nevertheless, IE has also to be open and exploratory if the WG is to develop to meet future, possibly different requirements.
- The Annual meeting is a combination of IE, CP review and Strategy discussion, with technical activity encouraged throughout the year.
- We intend to try to maintain this method of working!

WG3 Conclusions

- WG3 is active, uses a combination of information exchange and formal collaboration to provide benefits to all three participants.
- A good working relationship exists amongst the participants.
- EUROPA allows development of the existing successful pattern to meet new needs, and improving links with CEPAs etc.

F.10 Energetic materials – future directions – Adam Cumming

Energetic Materials Future Directions

Adam Cumming

ANNC WG3 – September 2004

Introduction and Background

- UK integrated most aspects of Energetics Research
- Synergies provided new routes for exploration
- New materials and approaches affecting approach
- Awareness of new threats and new requirements
- ‘Traditional’ approach seen as ‘worn out’
- Process of revolution under way
- Not traditional chemistry

Past & Present

- It is important to understand how the present technology base was produced, and why.
- It is also important to realise that other nations, with whom we now work closely, have a different history
- This is the foundation from which we work!
- Military expectations also form part of this base!

Changing Perspectives

- Threat has changed and therefore the direction will need to change.
- How much do we really understand of performance etc?
- What will be the expected life; expected performance and vulnerability?
  - Capable of withstanding terrorist attack?
  - Flexible and effective enough to be deployed easily
  - Answer questions from users - ‘what if?’
  - Can we do something different?

New Approaches

- Novel formulations manufacture -must be understood
- Use of Energetic Thermoplastics in compositions
- Predictive tools for performance and vulnerability
- Nanometric materials - metals and non-metals
- Use of nanotubes and other novel systems
- Application of new understandings to existing needs
- Change the whole basic approach - challenge the assumptions!

Available Materials

- New Materials and new classes of existing materials
- Modelling of performance and material interactions
- Totally new concepts
  - polynitrogen etc
  - availability of Russian technology
  - understanding of basic physics and chemistry
- All these have limitations and strengths - these need to be understood in the context of the application in a weapon, or as a threat to our forces.

Prospects for new materials, a UK perspective

- There are several materials available. The UK view is that not all can be successful as the market is too small.
- Any new material must show a real benefit of some kind.
  - Performance
  - Flexibility in Operations
  - Life and Disposal
  - Cost
- The UK programme includes assessment of potential options.

Binders

- **GAP**
  - Available, but has some problems
- **PolyNIMMO**
  - Well characterised
- **PolyGLYN**
  - Stability problem now overcome
  - Formulation studies under way
- **Thermoplastic Elastomers**
- **Reversibly Crosslinked Polymers**

Energetic Thermoplastic Elastomers

Next Generation of Energetic Binders

Elastomer at normal temperatures

Melts reversibly at high temperatures

Have they are role?

Can they be used economically?

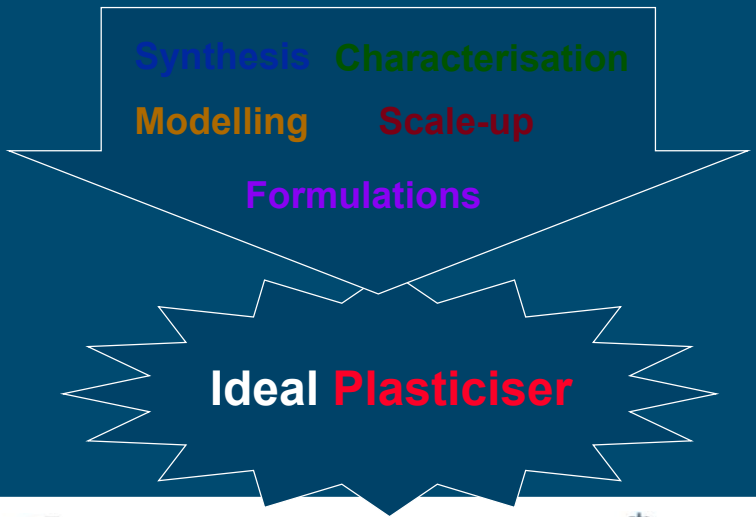
Advantages

- Elimination of isocyanates
  - reduce environmental impact
  - reduce gassing, improve filling quality
  - increase pot life
- Reprocessible
  - Less Waste products
  - reduce disposal costs
- Control of Mechanical Properties
- Continuous processing

Plasticiser Requirements

- Desired effect on all aspects of performance and safety.
- Desired effect on processing.
- Desired effect on mechanical properties.
- Physically/chemically compatible.
- Stable/Safe to handle/Low toxicity.
- No/low migration or loss on ageing.
- Cheap, available and low environmental impact

Interdisciplinary Approach



Prospects for new materials, a UK perspective

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- Any new material must show a real benefit of some kind.
  - Performance
  - Flexibility in Operations
  - Life and Disposal
  - Cost
- The UK programme includes assessment of potential options.

New Materials Assessment

- CL20 - sensitive, but appears to be possible to manage
- ADN - Some problems but a possible option
- HNF - instabilities make it unlikely to have a future
- FOX - 7 - Interesting but more definition of performance and vulnerability needed
- Binders - All energetic binders still looking for a real role.
- Most of the others appear to be niche materials but….
- NB Assumptions on novel materials may prove to be wrong: modelling vs reality!

Novel Explosives

- Nothing we have is ideal!
- Tend to evolve technology for applications
- Russian technology available - different assumptions?
- Technological surprise - we do not know all that we thought we did!
- Blast a significant tool
- Need to apply what we do know and what we have learned to novel and existing systems
- Systematically examine gaps!

Novel Materials

- New grades of Aluminium may improve performance
- Already available and being examined
- Part of a move towards making explosives fit for application and removing possible inhomogeneity
- Eases prediction problem?

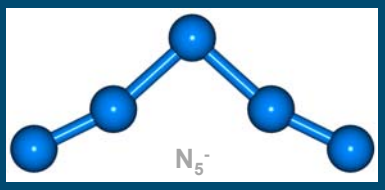
- Organic filler materials also need examination
- Control of particles size, shape, etc important?
  - How important? Does it matter?

Nitrogen Species

- UK studies on synthesis examining options
  - Can they be made?
  - If so how, and will they really be stable
  - Will the performance meet the initial predictions?
- UK worked in partnership with FOI in Sweden
  - Laser driven synthesis and matrix isolation
  - Moving from traditional organic chemistry
- Need to understand the benefits/limitations

Break-through for HEDM

First all-nitrogen compound in more than a century. Stable but needs uncommon counter ion (e.g. SbF_6). Research towards other counter ions are in progress, e.g N_3^-.

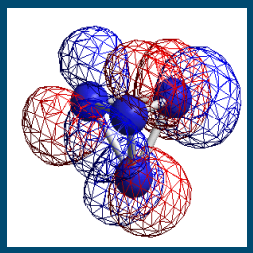


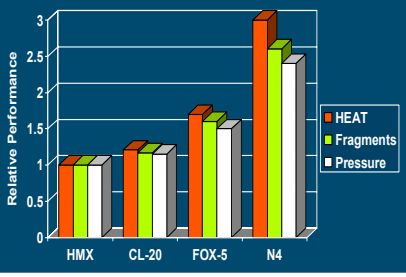
Potential: +100%

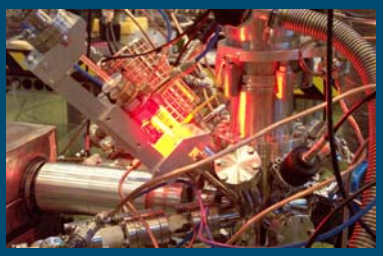
Revolutionary HE:

Nitrogen Clusters (e.g. N_4)

- Theoretically possible HEDMs
- Experimental work in progress
- Potential 300-500% of HMX
- Time frame: 10-20 years





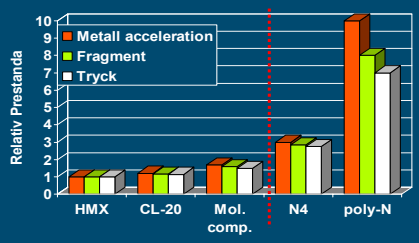


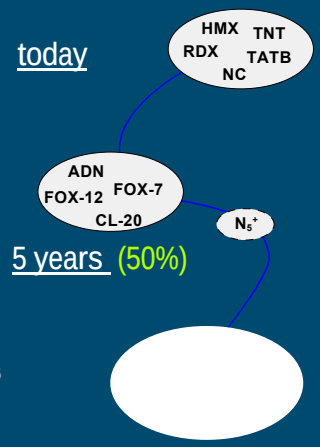
Metallic Hydrogen

- Meta-stable high-pressure form of hydrogen
- Performance 32 * HMX
- Quantum Mechanically Determined
- Experimentally Detected (LLNL)
- Principle of Synthesis: High pressure (by light gas gun)

The world's best Chemical Explosive !?

Conclusions from Swedish researchers





- Research on new energetic materials is far from exhausted
- Much higher performance is possible

Hazard Modelling

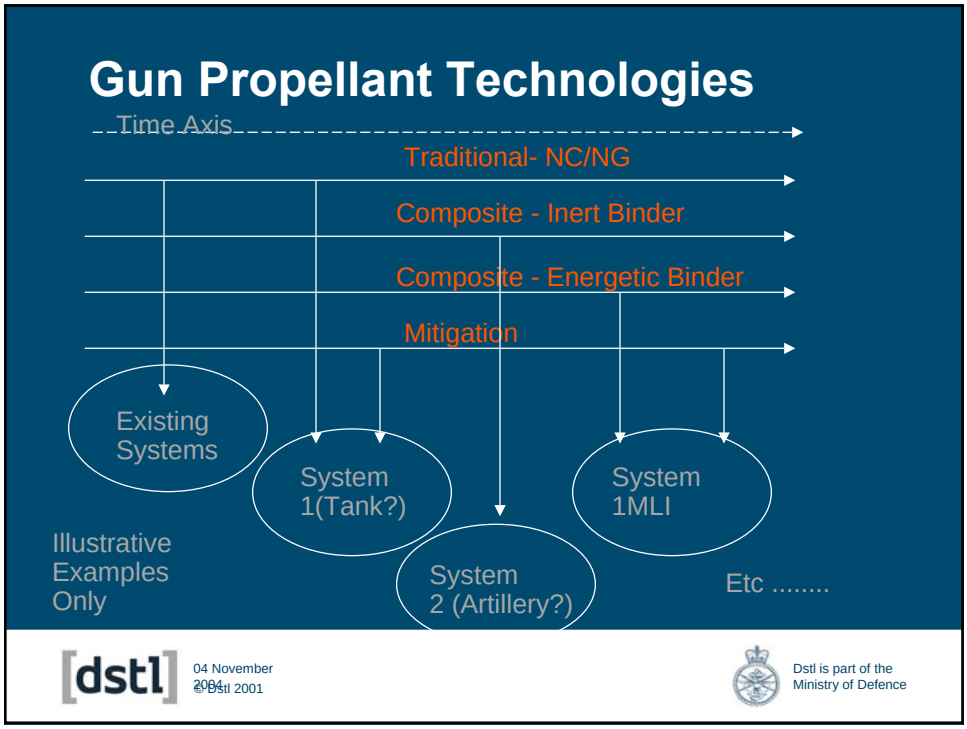
- Strong UK Focus at present
- Emphases
  - developing improved constitutive model for PBX
    - adequately describes heat localisation
    - describes “damage” realistically
  - developing improved ignition and growth model
  - current focus on shock stimulus

Thrusts

- Use of modelling to probe stimulus / response curve - not replace tests, but increase confidence in test results
- Early hazard assessment of future energetic materials
- Use technology developed for understanding hazard response to assist with other issues (ERA, penetrators)

Explosives and Propellants

- There is a common technology amongst explosives and propellants.
- Similar ingredients used
- Similar processing methods
- End use different
- Blast now being considered as option
- Performance available, but needs matching to system


Gun Propellant Technologies
Time Axis
Traditional- NC/NG
Composite - Inert Binder
Composite - Energetic Binder
Mitigation
Existing Systems
System 1(Tank?)
System 1MLI
System 2 (Artillery?)
Etc .....
Illustrative Examples Only
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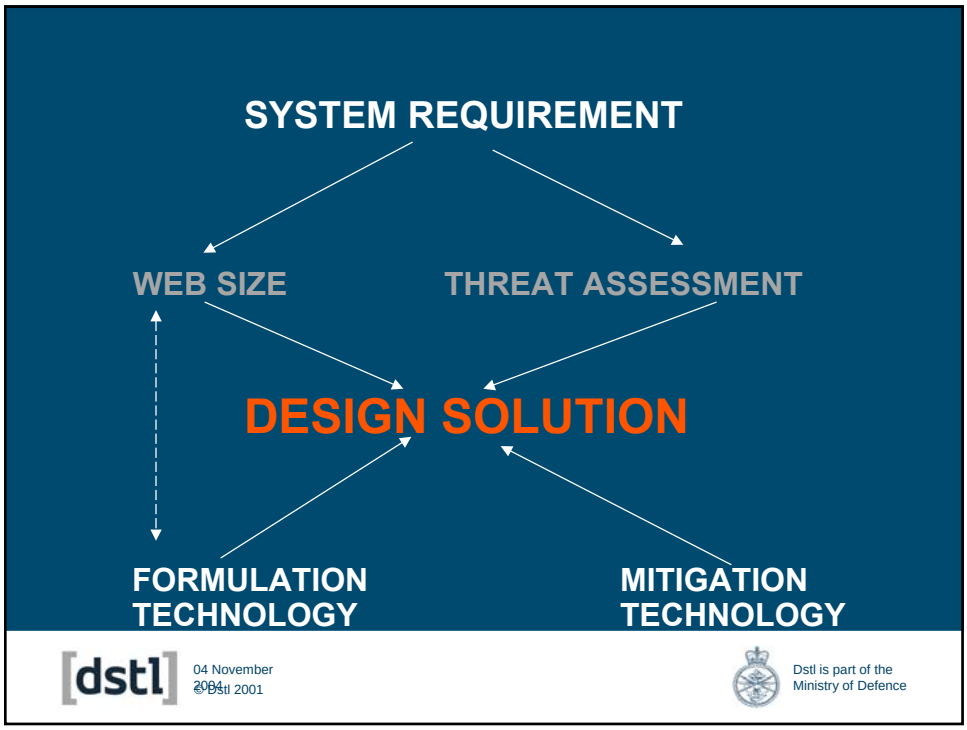
SYSTEM REQUIREMENT
WEB SIZE
THREAT ASSESSMENT
DESIGN SOLUTION
FORMULATION TECHNOLOGY
MITIGATION TECHNOLOGY
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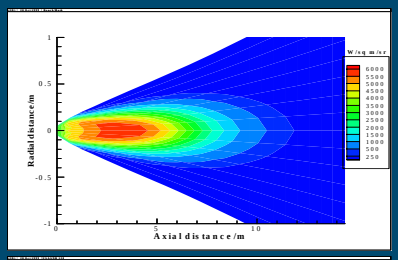
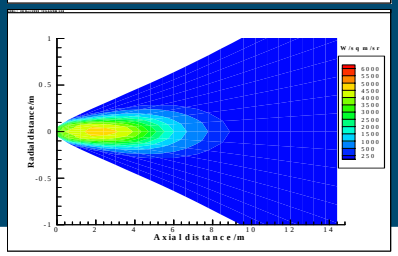
Missile Propulsion

- New solids materials give options
- Solid propulsion one part of solution. Appropriate blend of options must be examined
- New solids appear to give required thrust, but needs proving and demonstrating!

Typical Signatures
Plume Predictions - Contours of Radiance



Double Base



Min Smoke Composite

Other Options

- Still tendency to use traditional chemistry
- Other options exist - are they real?
  - Need predictive tools
  - Need integrated approach
  - Need to answer question - ‘So what’
  - Energetics a System Component, therefore what do new concepts do to the system?
  - Can we re-engineer the system, and is it worth it?
  - Prove it!

Conclusions

- Several options available
  - Short term evolutionary
    - Understanding of processes necessary
  - Medium Term moving away from ‘traditional’ materials
    - Do we know how to exploit these opportunities?
  - Long Term mix of chemical and non-chemical systems.
    - Can we do it?
    - Is it sensible?
    - Is it needed?

F.11 Surveillance and Service Life Extension – Status Norwegian Policy – Tove Karsrud

FFI Forsvarets forskningsinstitutt

Surveillance and Service Life Extension Status Norwegian Policy

ANNC Meeting
September 2004
Tove Engen Karsrud

Policy project

- The objective is to develop a basis for a realistic policy for surveillance and if possible service life extension for the missiles of the Norwegian Defence
  - The rocket motor will be focused
- Duration :
  - January 2003 – June 2004 (=> end of 2004)

Norwegian policy

- Norway does not have a unified policy regarding surveillance and life time assessment of munitions
- Surveillance programs have been taken care of by the individual missile projects and have been executed by the Material Command in charge

Background – Norwegian conditions

- The Material Commands in the Norwegian Decence felt that they did not have the necessary knowledge to contribute when surveillance and service life programs were established
  - May lead to more extensive and costly programs than necessary
  - May lead to programs not taking care of specific Norwegian conditions
- The Material Commands wanted more internal cooperation and sharing of knowledge

Background - general

- Surveillance and service life extension of missile components seem to be of increasing importance
- Reduced budgets to the Defence
- Operational service life is extended
- Need to extend the technical service life to fit the extended operational service life
- Increase knowledge of surveillance testing
- Increase knowledge of ”the missile’s life”

Work schedule policy project

- State-of-the Art Survey
  - Literature study
  - Contacts with Norwegian and internatonal institutes and companies
  - Focus on specific Norwegian conditions
- Create a forum for surveillance and service life extension
  - FFI and the Material Commands
  - Exchange of knowledge and discussions on the way ahead
- Develop a basis for a Norwegian policy for surveillance and if possible service life extension for missiles

Present surveillance programs

- Surveillance programs have been organized in missile projects under the Material Command in charge
- FFI has collected information on present surveillance programs and presents the information in a report
- The report contains also a brief description of each missile
- Variations of the surveillance programs :
  - number of participants
  - degree of participation
  - level of information
  - test program
  - costs

Literature study

- Policy documents from other countries
- General literature
- Methods to determine service life
  - testing
  - modelling
- Surveillance testing
- Surveillance programs

Forum for surveillance and service life extension

- Participants from FFI and the Material Commands/FLO/AMM
- A one day meeting is arranged twice a year at FFI
- On the agenda
  - Policy matters
  - Surveillance programs
  - Surveillance testing
  - Technical matters
  - Relevant matters

Life time assessment - Norway

- Identify what kind of factors and environmental impacts which will influence the service life of Norwegian missiles
- What can these factors and impacts lead to ?
- What can happen in a missile during ageing ?
- What kind of incidents and accidents have occured with Norwegian missiles and what are the reasons ?

Factors which may influence life time

- Temperature
- Temperature change
- Humidity
- Oxygen
- Impact
- Vibrations
- Kinetics
- Chemical processes
- Handling
- Packing
- Operator
- Electrical impulses

What may happen in a rocket motor

PARAMETER	Can lead to
Change of temperature	Cracks, debonding, gas evolution, decomposition changed : burn rate, sensitivity, kinetics, mechanical properties
Humidity	Gas evolution, cracks, chemical reactions changed : burn rate, mechanical properties
Oxygen	Chemical reactions changed : burn rate, mechanical properties
Impact	Cracks, debonding, changed sensitivity
Vibrations	Cracks, debonding, changed sensitivity

Incidents and potensial results

Incident	Can result in
Cracks in propellant	Increased burn rate and motor pressure, motor burst
Debonding	Increased burn rate and motor pressure, motor burst
Altered burn rate	Altered thrust and functionality, motor burst
Damaged O-rings	Leakage into the motor, altered thrust and functionality
Changed sensitivity	Ignition, unwanted reaction, detonation

Accidents with rocket motors and reasons

Accident	Caused by
Motor burst	High motor pressure, high burn rate, gas evolution Closing of nozzle, changed burn rate and mechanical properties
Detonation	Impact, electrical impulse, gas evolution, altered sensitivity
Changed functionality	Changed burn rate, malfunction of seeker, leakage into motor
No ignition of motor	Malfunction of ignitor, leakage into motor, altered chemical composition

Information on incidents and accidents with Norwegian missiles

- What kind of incidents have been discovered and stopped ?
- Why has the incident occured ?
- How was the incident discovered ?
- What could have been the result of this incident ?

- What kind of accidents have taken place ?
- Why did this happen ?
- Could the situation have been prevented ?

F.12 Update on UK life assessment activities – David Tucker (presented by Mark Wasko)

Notes

ANNC Meeting September 2004
Update on UK Life Assessment activities

David S Tucker

Energetics Technology Department

Dstl Fort Halstead

Sevenoaks, UK

ANNC Meeting September 2004

•Priority areas: - unchanged from 2003

- Improve in-service surveillance
- Identify critical failure mechanisms
- Data logging - Asset Tracking
- Sensor development including chemical, MEMS
- Cost Benefit Analysis - whole lifecycle costing

Notes

ANNC Meeting September 2004
Whole Life Assessment of Munitions

- MCBU (Munitions Corporate Business Unit), part of the Defence Logistics Organisation, is the UK MOD focus
- Intention is to set up an Integrated Support Team with a core of MCBU staff and “virtual” members from other MOD agencies to implement policy on whole life assessment
- MCBU plans to fund a 5 year programme with the objective of producing an environmental data logger suite for various munition applications. Funded from MOD Research Building Block (Output 6). Early indications were that this would be awarded in late 04 after open competition although a delay seems likely.
- Open Day for Industry held at RMCS Shrivenham in April 04 to publicise WLA activities and the proposed EDL contract.

ANNC Meeting September 2004
Whole Life Assessment of Munitions

- QinetiQ Fort Halstead has received a 3 year research contract funded from MOD Research Building Block (Output 4), commencing September 04
- Desired Outcomes:-
- Provide the methodology and expertise required to generate failure and lifing algorithms (for energetic materials in munitions)
- Expand the development of algorithms for the behaviour of energetic materials into composite propellants and fibre reinforced composite materials
- Model the failure properties of materials so that less testing will be required in future MOD surveillance programmes
- Develop new, safe and environmentally acceptable pyrotechnic compositions with improved stability and longer service lives

ANNC Meeting September 2004

Interfacial Failure in Rocket Motors (QinetiQ, Fort Halstead)

- A project , recently completed, to study adhesive bond failure in solid rocket motors
- Aims were to improve both structural adhesive bonding of motor cases and also critical propellant adhesive bonds
- A new catalyst has been devised for silane pretreatment of steel strip laminate prior to epoxy bonding; patent pending
- A rubber modified epoxy adhesive for rocket motor bonding applications has been developed
- Improvements have been proposed to bonding of CDB propellants to hypalon rubber and also composite propellants to hypalon and EPDM rubbers

ANNC Meeting September 2004
Whole Life Assessment of Munitions

- QinetiQ (Fort Halstead) has produced a “technology roadmap” for environmental data logging. A UK contribution to the NATO AVT-119 CDT on Health Monitoring of Munitions
- Defence Packaging Unit (Fort Halstead) is maintaining a database of sensor readings from ammunition. As more dataloggers will be deployed and monitoring more than just temperature and humidity, this has the potential to become a vast undertaking
- Controlled temperature storage. The UK has built 6 storage sheds in Iraq to maintain a cool environment at around 21°C. Cost savings are judged to be significant given that ammunition in A1 (severe, hot, dry) conditions may be limited to 6 months life
- Individual weapons may have storage criteria for temperature and humidity but they vary widely and there is no UK “standard” for storage buildings

Notes

UK AMMO STOCKS - IRAQ

Open desert storage 2003

Temperature conditioned storage shed under construction ASP Shaibah

F.13 Reassessment of Dutch EOD safety distances – Howie Lodder

Phase 3: aircraft bomb fragmentation trials

Reassessment of the Dutch EOD safety distances

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Krz Ih Orgghu

Contents presentation

- History of project reassessment VGVK-19
- Purpose VGVK-19 phase III
- Test preparation
- Performed tests
- Blast measurements
- Fragment distances
- Preliminary conclusions
- Tasks still to be preformed
- Questions

Reassessment safety distances – phases I & II

- **Why reassessment of Dutch EOD manual, VGVK-19?**
  - Doubts about accuracy within EOD community
  - Start of research programme discussed
- **Project commenced 1995**
- **Purpose phase I: Determine origin of safety distances**
  - Where did the distances come from and what were they based on?
- **Purpose phase II: Determine safety distances for NEQ <25 kg**
  - Trials performed in NL
  - Safety distance for fragments in VGVK-19 for NEQ <25 kg in peacetime is 190m

Phase II tests at Vlieland, NL

Results phase II

Ammunition article	Fragment distance (m)
NR 20C1, hand grenade	115
2” NR 19 mortar	74
81 mm, L41 mortar	176
105 mm, NR68 artillery	315
120 mm, NR104 mortar	450
155 mm, M107C1 artillery	542
8”, M106 (TNT) artillery	723
8”, M106 (CompB) artillery	697
≤ 25 kg NEQ fragmentation hazard	190

Reassessment of safety distances - phase 3

Aim:

- **To obtain fragment safety distances for aircraft bombs with/without fragment mitigating techniques**
  - Effect studied:
    - Fragmentation
    - Blast

Test series

- **Target area**
  - Location: Hjerkinn - Norway
  - Target area covered with gravel to facilitate fragment search
  - Flat target area of 600 m x 400 m
  - Possibility of carrying out work within target area
- **6 x MK 82 500 lb aircraft bombs used for the tests**
  - 89 kg Tritonal (= 110 kg TNT equivalent)
- **Performed tests:**
  - Test 1: sand cover
  - Test 2: open pit
  - Test 3: open air
  - Test 4: protective structure
  - Test 5: open air
  - Test 6: sand cover

Test series - 2

- **Mitigating techniques based upon what is actually used by the EOCKL**
  - Rule-of-thumb 10 calibres sand cover
  - Protective structure utilising ISO-containers
- **For the trials:**
  - ”worst-case scenario” constantly tested
  - Open air test used as reference
  - Simulation model used to:
    - approximate distance of furthest fragment
    - Determine detonation location
    - Determine throw-out angle of fragments
  - Fragment location noted using GPS
  - Initiation in nose pocket

Test-site: Hjerkinn - Norway

Test 1: 10 calibre sand cover (70 m^3)

- **MK 82 with 10 calibre (70m^3) sand cover on gravel**
- **Blast measured using 12 blast transducers divided over 3 directions**

Results:

- **227 fragments found**
- **Fragment distance max 240 m**
- **Large Blast mitigation due to presence of sand**

Test 2: open pit

- **MK 82 in open pit 5 m deep**
- **Octagonal Pit, 5 m in diameter**
- **Blast measured in 1 direction using 5 blast transducers**

Results:

- **25 fragments found**
- **Fragment distance max 534 m**
- **Lug found at 735 m**

Test 2: pit construction

Test 2 - crater

Test 3: open air

- **MK 82 on relatively soft (marsh-like) base**
- **Acceptor bombs (18-20 m)**
- **Witness plates at 40/70/100 m**
- **Blast measured in 3 directions**

Results:

- **61 fragments found**
- **Fragment distance max 888 m**
- **Witness plates at 100 m perforated**

Test 3 – position of acceptor ammunition and witness plates

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Test 3 – Perforation witness plate at 100 m

Test 4: Protective structure

- MK 82 in open put, 5 m deep covered with ISO-containers
- Octagonal Pit, 5 m in diameter
- Top ISO-containers filled with 55 cm sand
- Blast measured in 3 directions

Results:

- Almost all fragments stopped (10 recovered)
- Fragments found at a max distance of 114 m
- One container fragment found at 212 m
- All fragments found were small and deformed due to impact with ISO's

’ Uhdvvhvvp hq’ ri ’kh Gx’fk HRG vdih’| glv’dqfhv DQQF/57 Vhs’ 5337 54

’ Uhdvvhvvp hq’ ri ’kh Gx’fk HRG vdih’| glv’dqfhv DQQF/57 Vhs’ 5337 55

’

Test 5: open air

- MK 82 on gravel base
- Harder (stone) base compared to test 3
- Acceptor bombs (18-20 m)
- Witness plates at 40/70/100 m

Results:

- 41 fragments found
- Fragment distance 838 m, probably 956 m
- Witness plates at 40 and 70 m perforated / hit

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Test 5 – Perforated witness plate at 40 m

Test 6: 15 calibre sand cover (190 m^3)

- 15 calibre (190 m^3) sand cover on gravel base
- No blast measured

Results:

- 69 fragments found
- Fragment distance max 41 m
- Lugs & charging well found at 34, 47, 64 m

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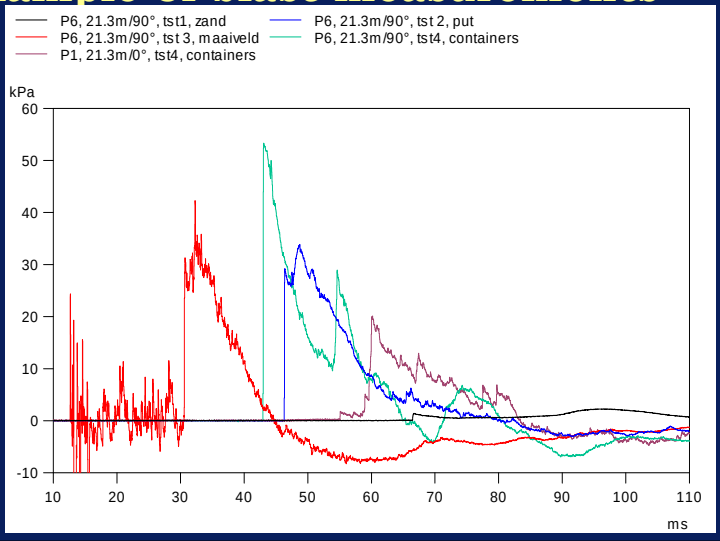
Example of blast measurements



Results of blast measurements, compared to open air tests

- Blast open pit very similar to open air
- Sand cover strong mitigator
- Increased blast level at front of protective structure (blast focussing)
- Reduction of blast at side of protective structure compared to open air test

Results of fragment distances

Performed tests	Fragment distance (m)
Test 1: 10 cal. sand cover	240
Test 2: open pit	534
Test 3: open air	888
Test 4: Protective structure	114
Test 5: open air	838 / 956
Test 6: 15 cal. sand cover	41
125 kg NEQ fragment distance	425

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Test results

- **Fragment distances determined**
  - Furthest fragment found during open air test
  - Reduction in fragments due to mitigating techniques
- **Blast measurements performed**
  - Reduction in blast for sand and protective structure (side)
  - Increase in blast front of protective structure
  - Open air and open pit test almost identical
- **More insight into mitigating techniques**
  - Fragment distances dependent on amount of sand used
  - Protective structure tested

Tasks still to be performed:

- **Norway results draft report currently being evaluated by Dutch EOD**
- **Determine new safety distance for different ammunition articles not tested**
- **Closer look at rogue fragments**
- **Compare distances to other EOD manuals**
- **Fragment distances for different calibres of WWII bombs will be determined from these results + other simulations**
- **October/November 2004 – EOD manual with revised safety distances**

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QUESTIONS

F.14 Urban warfare simulations – Maarten Manders

ANNC Fall 2004 meeting

Urban Warfare Activities

WQR Ghihqfh Uhvhdufk

Contents

- Small Unit Operations Research Programme
  - Objective
  - Overall result
  - Work packages
- Work package: Operations in Built-up areas

Objective of Small Unit Operations Research Programme

Programme Objective

Development of knowledge, skills and infrastructure to quantify and/or qualify the operational effectiveness of small unit operations in the spectrum of peace support operations

Required expertise

- Operations research
- Military subject matter experts
- Software engineering
- Equipment specialists
- Human behaviour representation
- Group interaction

Crisis Response Operations

- Other Operations and Tasks
- **Peace Support Operations**
  - Conflict prevention
  - Peace making
  - Peace keeping
  - Peace enforcement
  - Peace building
  - Humanitarian relief

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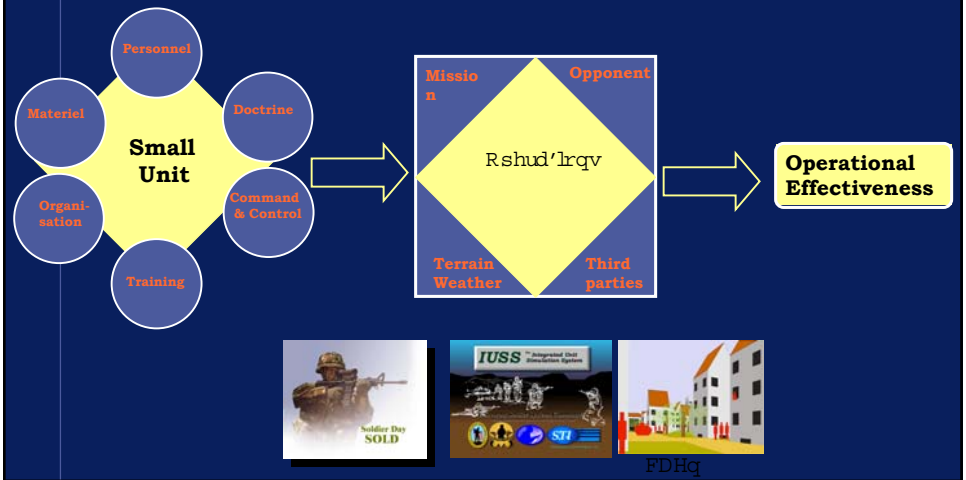
Overall Result

The capability to translate and to integrate the individual developments in the areas Doctrine, Command & Control, Training, Organisation, Materiel and Personnel into the operational effectiveness of small units.



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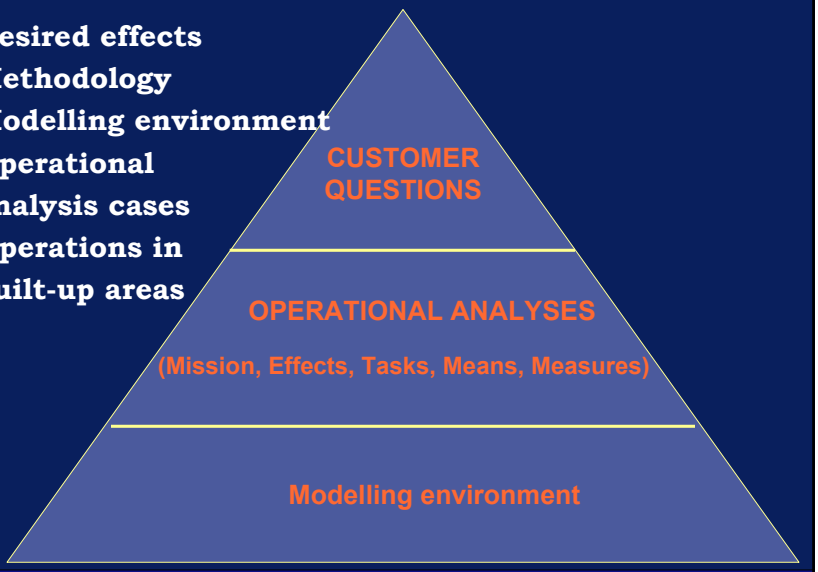
Work Packages

- Desired effects
- Methodology
- Modelling environment
- Operational analysis cases
- Operations in built-up areas



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Work Package: Operations in Built-up Areas

Current and planned activities

- Participation in IST-46 group (urban warfare)
- Mobile communication means
- Survivibility concepts for Combined Arms Teams (recently started)
- Protection against non-military threat in urban environments (recently started)
- Logistic and medical concepts for urban warfare (2005)

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More information
Programme manager
Ellen N. Van Son-de Waard (son@pml.tno.nl)
Deputy programme manager
Bob Barbier (barbier@fel.tno.nl)

F.15 Directed Energy Weapons – Jurgen Timpert

Three kinds of DEW

- **High Power Microwave (HPM)**
  - **Anti-Electronics**
  - **Mobile and versatile**
  - **Deployable in near future**
- **High Energy Laser (HEL)**
  - **Hard-kill weapon**
  - **Fast and accurate**
  - **Deployable around 2020**
- **Particle Beam Weapons (PBW)**
  - **Exist as controversial idea only**
  - **Possible deployment around 2???**

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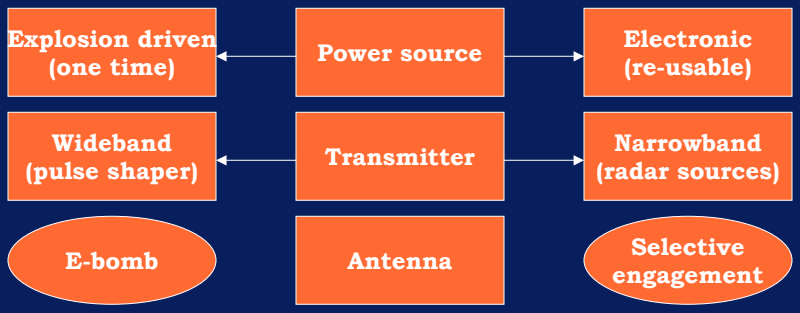
Forms of HPM

- HPM weapon delivers high-intensity, high-frequency electromagnetic pulse which is not lethal to humans
- Generally consists of a power source, a transmitter and an antenna



HPM research at TNO… recent past

- Largely a practical effort
- Several demonstrators made
- Tests of HPM against PC's

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HPM research at TNO… Current and planned

- Vulnerability assessment methods for platforms
- How to integrate with other weapon concepts
- Improved HPM grenade demonstrator

Forms of HEL

- HEL weapon delivers intense light to target, transferring large amounts of energy without projectile
- Generally consists of a powerful laser, beam control optics and target acquisition systems
- Less mature than HPM

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HEL research at TNO… recent past

- Mainly a theoretical effort
- Material interaction models
- Models for lethality assessment
- Mine and UXO clearing

$$\sigma(x,t) = \frac{\alpha E}{1-\nu} = \left(-T + \frac{1}{L}\int_0^L T dx + \frac{12\left(x - \frac{1}{2}L\right)}{L^3}\int_0^L T\left(x - \frac{1}{2}L\right)dx \right)$$

HEL research at TNO… Current and planned

- Validation of interaction models with experiments
- Find, conceive and test countermeasures against laser
- Mines and UXO clearing demonstrator
- Find support for lethal weapon demonstrator

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PBW research…

- **Short literature study proved PBW's to be no realistic weapon**
- **Nice subject for SciFi though!**

The next step

- **To answer the question:**

Z kdwwkuhdwfdq d GHZ srvh wr d wdujhwB

- **And what do we need for that?**

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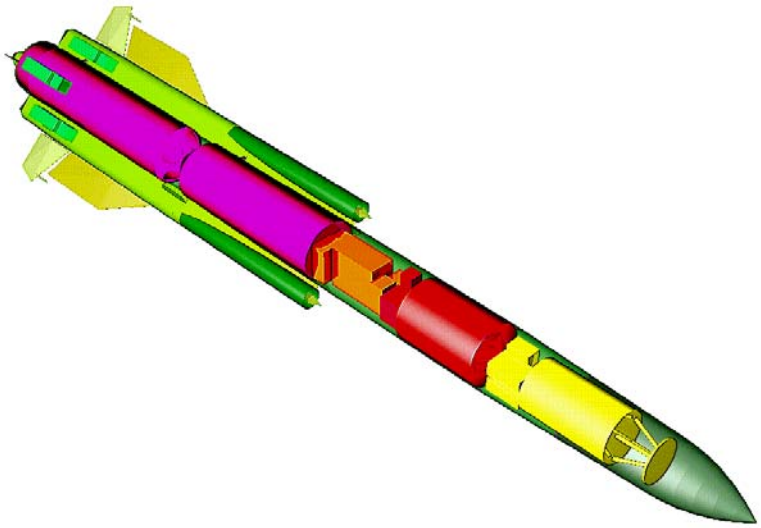
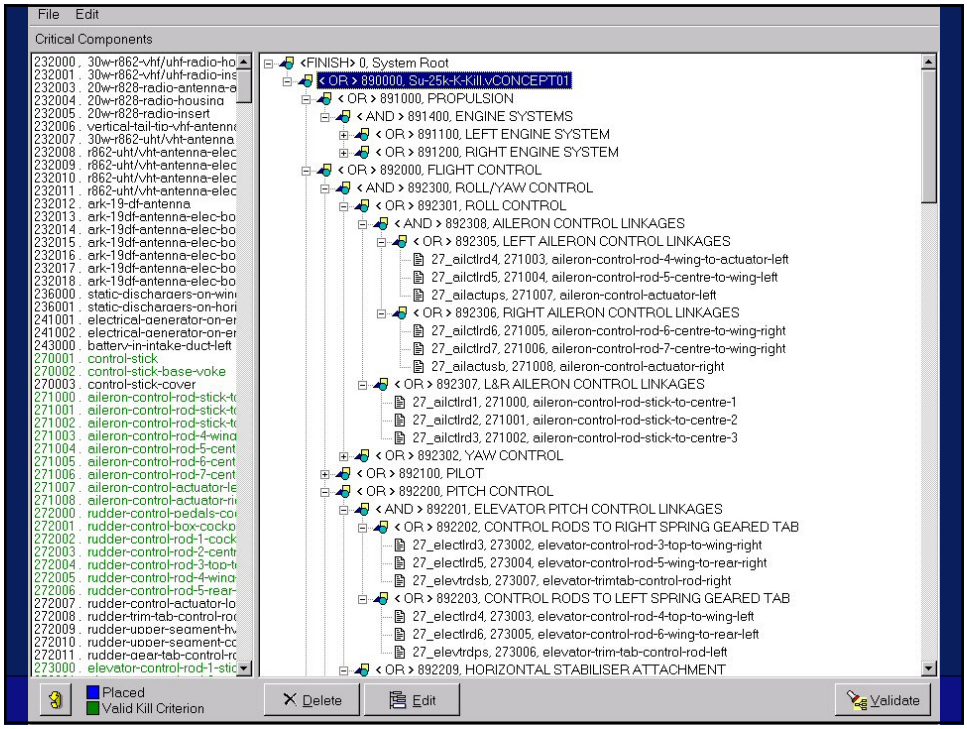
Vulnerability and lethality analysis: 3 components

- Geometrical target model: which parts are being affected by the weapon?
- System tree with failure criteria: what is the effect of component damage on the functioning of the entire system?
- Weapon effect models: What damage does a weapon do to the affected component?





Fill in the gaps…

- **HPM: determine field strength near electronic components**
- **Shot line approach not usable**
- **Cavities in target and electrical properties of materials**

- **HEL: determine irradiation on target component**
- **Shot line approach for projectiles and shrapnel very suitable for laser**
- **Optical and thermal properties of material**

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To do list

- Implement laser interaction models in existing V & L assessment code
- Devise a simulation for HPM propagation in platforms
- Develop HPM failure criteria
- V & L assessment of both HPM and HEL to determine operational value

- VALIDATION!!!

Questions?

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