

TTCP WPN Action Group 25 Novel Weapons Technologies

**Presented to
TTCP WPN TP 1, 4 and 7 Annual Meeting
27 February 2012**

DSTO Edinburgh, Adelaide, Australia

This document contains information which is provided in confidence to the Governments of Australia, Canada, New Zealand, the United Kingdom and the United States under The Technical Cooperation Program (TTCP) among these Governments. The information contained herein may be used and disseminated for national Defense Purposes only within the recipient Governments and their national defense Contractors. The recipient Governments will ensure that any other use or disclosure of the information is made only with the prior written consent of each of the above Governments.

Att 4

ADB 397830

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE FEB 2012	2. REPORT TYPE	3. DATES COVERED 00-00-2012 to 00-00-2012			
4. TITLE AND SUBTITLE TTCP WPN Action Group 25 Novel Weapons Technologies		5a. CONTRACT NUMBER			
		5b. GRANT NUMBER			
		5c. PROGRAM ELEMENT NUMBER			
6. AUTHOR(S)		5d. PROJECT NUMBER			
		5e. TASK NUMBER			
		5f. WORK UNIT NUMBER			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) TTCP/The Technical Cooperation Program/Subcommittee, on Non-Atomic Military Research And Development, , ,		8. PERFORMING ORGANIZATION REPORT NUMBER			
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)			
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)			
12. DISTRIBUTION/AVAILABILITY STATEMENT Distribution authorized to US Government agencies and their contractors; Foreign Government Information; 16-10-2000; TTCP MOU Amendment One, OUSD (AT&L)/DDR&E/ITP, 3080 Pentagon, Washington, DC, 20301.					
13. SUPPLEMENTARY NOTES Proceedings of the 37th Meeting, DTSO Edinburg, Vol 2, WPN Group Conventional Weapons, Technology Technical Panel, WPN TP-4, Energetic Materials and Propulsion Technology, 27 Feb-2 Mar 2012					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT 5	18. NUMBER OF PAGES 40	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Outline



- **Terms of Reference**
 - **Scope**
 - **Responsibilities**
 - **Participants**
- **Status**
 - **Summary of Activities**
 - **Discussion of Methodology**
 - **Deep Dive Technology Survey**
 - **Rating of Technologies**
 - **Preliminary Recommendations**
 - **Summary of Future Activities**

Scope



- **Novel weapons technologies include but not limited to:**
 - **Energetic Materials**
 - **Directed Energy**
 - **Micro-Weapons / Munitions**
 - **Swarming Multi-Agent Systems (except for Micro-UAVs)**
 - **Autonomy and Emerging Algorithms for Guidance and Control**
 - **Basic research leading to novel weapons concepts**
 - **Novel uses of existing technology**
- **TRLs to be considered are 1-4**
- **Account for other relevant activities**
 - **Other TTCP Groups – MAT, LND, SEN and EWS**
 - **TPs in WPN Group**
 - **Intel community**
 - **AG-24 Managed Lethality Weapon Systems**
 - **Other non-TTCP collaborations including NATO Panels**

Responsibilities



- **Survey and review current activities in the field, both amongst the participating nations and other countries**
- **Make an assessment of the current state of novel weapons technologies**
- **Identify the main scientific and technological challenges remaining to reduce the technical risks and costs associated with the development and deployment of selected novel weapons technologies**
- **Make recommendations for future international collaboration, under the WPN Group and other TTCP Groups**
- **Provide a final report on the results of the effort to the 40th WPN Group meeting (May 2011)**

Participants



AG 25 Membership

- **Australia**
 - **Craig Hardie** **DSTO**
- **Canada**
 - **Paul Harris** **DRDC**
- **United Kingdom**
 - **John Christensen** **Dstl**
- **United States**
 - **Brad Forch (Lead)** **US Army ARL**
 - **Edward Bradley** **US Air Force AFRL**
 - **Stuart Blashill (Mentor)** **US Navy NAWC**

WPN TP Representatives

- **TP 2: Peter Plostins** **US Army ARL**
- **TP 7: Willy Toledo** **US Army ARL**

Summary of Activities



- **Held Leadership telecon: 7 June 10; Member telecons: 30 March, 27 April 11 and 10 Jun 11.**
- **Held combined AG25/24 Workshop (19-22 July 10)**
- **Completed Deep Dive technology survey**
- **Rated and Prioritized technologies based on “Level of Interest” and present “Funding Levels”**
- **Consulted Next Revolution in Military Affairs documentation produced by Naval Air Warfare Center Weapons Division**
- **Submitted draft final report for WPN Telecon, 15 Dec 10**
- **Formulated preliminary recommendations**

Discussion of Methodology



- The subject area of weapons technology is impossibly broad
- *The challenge is managing the complexity to increase the probability of identifying critical technologies (not missing technologies and correctly evaluating impact)*
- A process is required that minimizes the effect of subjective decisions and maximizes the possibility of investing wisely
 - It is obvious that there is no process that will even come close to guaranteeing success (predicting the future)
- **Simplified Three Step “Straw Man” Process (Inter-Related and Inter-Dependent)**
 - **Step 1: Focused on gaining historical, geo-political, sociological, military strategic and operational understanding of the world**
 - **Step 2: Focused on scanning the S&T horizon, guided by the knowledge and framework gained from the first stage, establishing technological relationships and groupings, and prioritizing**
 - **Step 3: Focused on a quantifiable evaluation methodology to determine which technologies have the greatest potential for significant impact**

Step 1: Understanding the World ...



A Perspective from studies in Next Revolution in Military Affairs (RMA)

- **Starting in about 1998, “NAWC Weapons Division, set out to determine what future wars would look like, what the flow of future military history would be, and what our world as an Armament Lab would look like”**
- **Based on studies in history of RMAs, constructed projections of future military evolution, built and studied scenarios of future geopolitical options**
- **Concluded that geopolitics were probably not going to be the major drivers of future military history, rather technology**
- **Emerging technologies that would reshape the world were advancing independently of the geopolitical scenarios**
- **To understand the nature of war, armaments, and the military coming age, we must look at the base technologies driving the new order, and then ascertain what effect they will have**
- **Must start with a review of the known, emerging technologies, and then project their growth and impact on military wars.**

Step 2: Scanning the S&T Horizon



A perspective from studies in Next Revolution in Military Affairs

- **Started a Technology Study Program to identify emerging technologies, their military potential, and their probable effect on future warfare**
- **From a larger list, identified 20 emerging technologies (prioritizing) they believed would have the greatest effect in the near term (1st half of the 21st century), plus 5 “possible/not improbable” technology developments that would “significantly change our world if they occur”**
 - **Computer technology**
 - **Human Language interface for computers**
 - **Robot technology**
 - **Fullerene chemistry**
 - **Bio-tech analysis instrumentation**
 - **Treatment of hereditary genetic diseases**
 - **Blood and tissue matching drugs**
 - **Neuroscience**
 - **Cellulose to glucose process**
 - **Chaos theory**
 - **Ubiquitous computing**
 - **Machine vision**
 - **Information technology**
 - **Multi-level coding system in DNA**
 - **Human bio genetic/chemical computer model**
 - **Control of bio-metabolic diseases**
 - **Tissue engineering**
 - **Neuropharmacology**
 - **Nanotechnology**
 - **Fuel cells to permit deep sea habitation**

Step 3: A Quantifiable Evaluation Methodology ...



A Methodology for Assessing Disruptions

- **NATO RTO SAS 026 Assessment of Possible Disruptive Technologies for Defence and Security**
- **NATO RTO SAS 082 Disruptive Technology Assessment Game: Extension and Applications**
- **It uses the red-blue teaming concept to determine:**
 - **Which emerging systems may be disruptive;**
 - **Which technologies may be useful to the future military in the defence & security context (Horizon II, or III).**
- **DRDC is using a process similar to this**
- **TTCP Joint Systems and Analysis Group (JSA) AG17 Emerging and Disruptive Technology Action Group (EDTAG)**
 - **“Provide an end-to-end process for identifying, assessing and reporting the defense and security implications of EDT developments”**
- **Applying this methodology is outside of the scope of this AG**

Deep Dive Technology Survey (1/5)



- **Part of Step 2 of the simplified process**
- **Explored approximately 300 technologies**
- **Public and closed sources**
- **Did not limit survey to conventional sources that focus on weapons technologies**
- **Included academic, institutional, scholarly sources and peer-reviewed or refereed articles**
- **Assessed technology readiness level and potential operational impact**

Deep Dive Technology Survey (2/5)



Directed Energy Weapons & Technology

Laser Technologies

- High Energy - High Power Lasers
- Solid-State Lasers
- Fiber Lasers
- Free Electron Lasers
- Attosecond Lasers
- Plastic Dye Rod Lasers
- Explosively Pumped Lasers
- SPASER Nano-Laser

Bending Laser Light

Laser Guided Energy

High -Power Microwaves (small)

Physics

Bose-Einstein Condensates

Electromagnetic Weapons

Electromagnetic Pulse

Nuclear

Conventional Tactical

Explosively pumped flux compression generator

Explosive and propellant driven Magneto-Hydrodynamic generator

Detonation Merging

Compressed Magnetic Flux - Magneto Hydrodynamic Explosive Munition

High power microwave devices

Compact EMP weapons

Electromagnetic kinetic energy devices

Power generation and storage

Atomospheric propagation

Thermal management

High Speed Weapons (MACH 5+)

Fuzing

Materials

Radomes

Sensors

Propulsion

GNC

Thermal Management

Boosters

Micro-Weapons / Munitions & Swarming Multi-Agent Systems

Swarming weapons and munitions

Direct operator control

Teleoperator control

Limited control

No direct control

MEMs based

Gun launched, projectile dispersed smart sub munitions

Micro-munitions (self-propelled)

Small Caliber Guided Munitions (< 20 mm)

Medium Caliber Guided Munitions (< 100 mm)

Swarming bullets and sub-munitions

Networks

Loitering Weapons

Transformable weapons

"Perching" weapons

Maritime loitering

Militarization of Space (Space-Based Weapons)

Space based anti-satellite and anti-missile systems

Space based ground attack systems

Ground based anti-satellite and anti-missile systems

Active Protection

Point (individual platform)

Area (encampment/battle group)

Theater (BMD)

Environmental Weapons

Environmental manipulation

Tailoring of weather patterns

High Frequency Active Auroral Research Program

Scalar electromagnetic waves/weapons

Deep Dive Technology Survey (3/5)



Non-Lethal / Less than Lethal

- Disruption of power grids
- Mechanical Entanglements
- Slime, Goo, Grey Goo, Foams
- Scalable Enhanced Blast
- Reactive Metals, Thermite Warheads and Bombs
- Super Lubricants
- Corrosive Materials
- Engine Disrupters and Combustion Inhibitors
- Obscurants
- Electromagnetics
- Electrical Incapacitating Devices
- High-Power Microwaves
- Malodorants
- Calmatives
- Irritants
- Flash-Bang
- Taggants to Mark Targets
- Blunt Projectiles
- Laser-Induced Biological Effects
 - Laser Dazzler
 - Laser heating
 - Laser Photochemical Effects
- Laser Guided Energy / Laser Plasma Channels
- Acoustics
 - Noise and Sound Generators
 - Sonic Bullets and Magnetic Acoustic Devices
 - Infrasonic Low Frequency Devices
 - Mosquito High-Frequency Devices
- Electrophonic Sound
- Bio-Effects and Neuroscience
 - Tuned Electromagnetic or Other Radiation Sources
 - Neuroreceptor Targeting Agents
 - Psychologically Targeted Acoustic Weapons
- Visual
 - Laser-Based Holographic Image Projection
 - Genetically Specific Targeted Effectors

Fundamental Understanding/Basic Research

- Nano-Structured Materials
 - Nano-Metals (other than Aluminum)
 - Nano Aluminum
 - Nano-Energetics
 - Nano-Engineered Energetics
 - Nanoscale Thermite Materials
 - Nano-Porous Silicon
- Graphene
 - Material studies
 - Weapons applications
 - Fuel catalyst
- Nano-diamonds
- Super atom clusters
- Coulomb explosions in nano-clusters
- Processing and Fabrication
 - Technologies for large volume production
 - Alternate Methods
 - Arrested Reactive Milling (ARM)
 - Energy Saturated Media (ESM)
 - Swaging
- Metamaterials
- Nano-Technology Weapons
 - Nano-molecular manufacturing of weapons
 - Nano-wire obstacles
 - Nano-tipped and/or coated projectiles
 - Nano-fragmenting projectiles and explosively launched fragments
 - Nano-metal warheads for MOUT
 - Nano-edged cutting weapons
- Novel Physics
 - Metastable clusters
 - Polymeric Nitrogen
 - Metallic Hydrogen
 - Structural Bond Energy Release in Strained Solids
 - Non-fusion ignition of sub-atomic reactions
 - Ballotechnics
- New materials formed at extreme pressure
- Polymeric Carbon Monoxide
- Nuclear Spin Isomers

Deep Dive Technology Survey (4/5)



Fundamental Understanding/Basic Research (Continued)

Anti-Matter

Atomic Propellants

Casimir effect gimbals/gyro

Multidisciplinary Computational Science

Coupled materials/electrodynamics/chemistry

Algorithms for coupling multidisciplinary physics

New Experimental methods for Verification and Validation of Multidisciplinary physics

Multidisciplinary data management/correlation/output

Multidisciplinary visualization

Multiscale Material Science

Algorithms for bridging material scales (including energetics)

New Experimental methods for Verification and Validation of at and across multiple scales

Multiscale data management/correlation/output

Multiscale visualization

Cold Fusion/LENR

Energetic Materials

New energetic ingredients

Fuels, oxidizers, binders, plasticizers, additives

Alane (AlH₃ - replacing aluminum)

ADN (replacing ammonium perchlorate)

Encapsulation and doping CNTs as energetic materials

Solid gun and rocket propellants

Liquid and gel rocket propellant

Explosives

Enhanced blast, fuel-air, and multi-phase blast explosives

Reactive explosive clusters

Novel metal complex explosives

Reactive materials

Penetrating energetic materials

Non-penetrating energetic materials

Structural energetic materials

Biosynthesis of energetic ingredients

Drivers

Insensitivity

Green-toxicity

Improved performance

Low signature and smoke

Cost

Systems level energy management (how distribution of energy use in the kill chain influences effect)

FOUO-TTCP-US, UK, Canada, AU

Propulsion

High-Speed Weapons

Ramjets

Ducted rockets

Scramjets

Dual Combustion Ramjets

PDE/PDRE

Undersea Propulsion

High-speed supercavitating rocket-propelled torpedo

Novel Propulsion

Magnetohydrodynamic augmented propulsion

Hypersonic MHD bypass propulsion

Blast wave accelerator

Laser driven propulsion

Ablative laser propulsion

Pulsed plasma propulsion

Electro-thermal chemical propulsion

Electromagnetic guns (rail gun)

Payloads

Blast Warheads

Thermobaric explosives

Fuel-Air explosives

Conventional

Energy managed approaches

Destruction of chem/bio

Penetrators

Barrier blind bullets

Vehicle and body armor

Bunkers and structures

CCM

Defeat of active protection

Kinetic Warheads

Replacements for DU/W

Selectable output

Deep Dive Technology Survey (5/5)



Guidance and Control

Actuation

- Adaptive flow control
 - Plasma flow control
 - Electro-active polymers
 - Magneto-rheological fluidic (MR)
 - Electro-rheological fluidic (ER)
- Multi-equilibrium structures
- Micro-thrusters

Sensors

- Advanced photovoltaics (COTS+)
- Light enhancement for optical systems
- Multifunctional structures
- Miniaturized radar
- Hyperspectral sensors
- LADAR/LIDAR
- Data fusion between sensors
- Micro active UWB radar array
- Chem/bio
- BDA

Algorithms

Hardware capable of handling emerging computational requirements

- Self-contained hardware
- Massively parallel

Advanced electronics (nano-technology, nano-electronics, molecular electronics ...)

Software

- Advanced Flight Controls
- Bio-inspired algorithms
- Neuroscience inspired algorithms
- Reduced State Guidance
- Magnetic Navigation
- Navigation in GPS denied environments
- Real time navigation initialization
- ATR

Signal Processing - real-time for swarms

Autonomy

Navigation

- MEMS Atomic Clock

Guidance and Control (Continued)

Power

- Energy harvesting
- Power sources - long duration and/or miniature
- Nano electronics
- Nano radios/antennae

Fuzing

Sensors

- Impact-sensor for adaptive fuzing
- Thin film magnetometers
- Seeker integrated fuzing
- Multi-point initiation

Materials and Structures

Nano-composites

- Carbon Nanotubes (CNTs)

Novel alloys

- Bulk metallic glass

Ceramics

Composites/hybrids

Multi-functional

Coatings

Polymers/plastics

Low observables

Morphing materials

Supporting Technologies

HWIL/Scene generation

- Database of scenes/maps/clutter (multi-spectral)

Projectiles

High fidelity M&S

Environmental

High g launch

Temperature

- Aeroheating from high speed

"Nanotechnology - New Ways to do Energetics"

Initiation-Specific Energetics

Nano-Encapsulated Energetics
(Reduced Sensitivity/Life Extension)

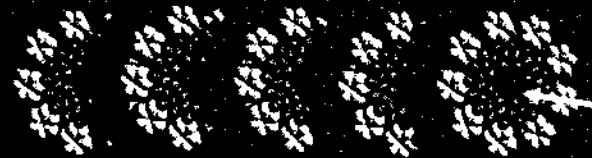
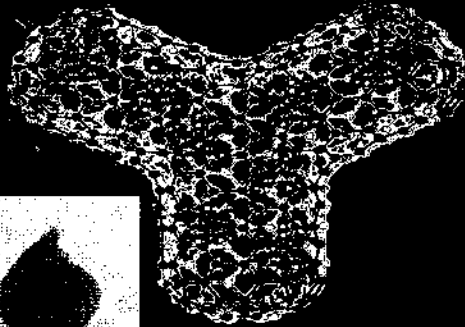
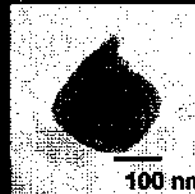
Nano-Engineered Energetics

Fuel

Oxidizer

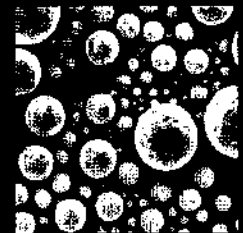
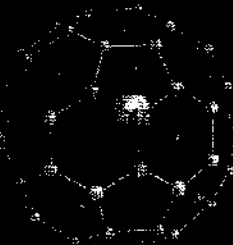
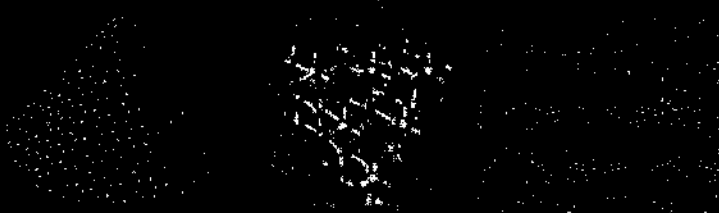
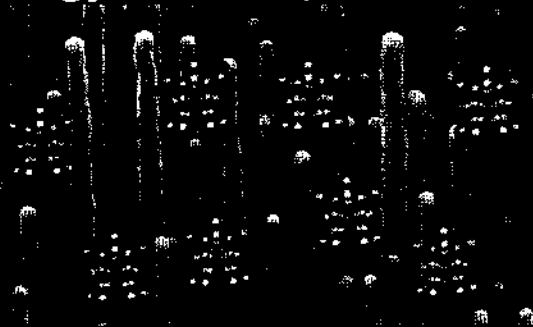
"Built from the Bottom-Up"

Nanocomposite
Reinforcement



Energetic Extended Solids
(All Bonds are Energetic)

Nano-Composite Energetics
(Intimate Mixing/Tailored
Energy Release)



Strain-Energy
Nano-Structured Materials
Stabilization in Structures

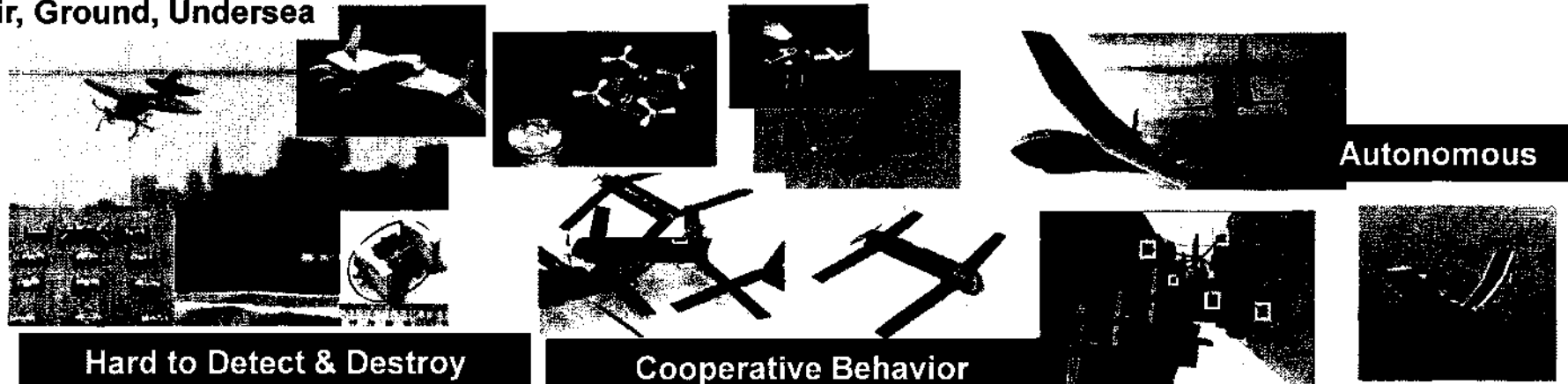
Nano-Metals/
Explosive Coated
Metals

Energetic Nanomaterials Have Many Technical Challenges – Stability, Power versus Energy....Interesting ongoing efforts to Store, Stabilize Materials within Nanostructures and/or the Structures Themselves - Not Just Burning them

Swarming Multi-Agent Systems & Micro Munitions



Air, Ground, Undersea



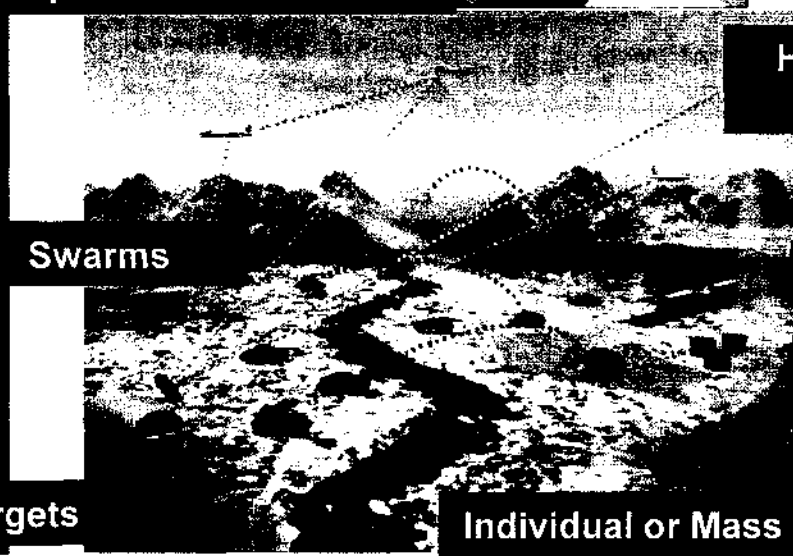
Autonomous

Hard to Detect & Destroy

Cooperative Behavior



Hovering & Loiter



Swarms



Zero in on Specific Targets

Individual or Mass Effects

The means to build these micro-weapons and control them is exceedingly difficult

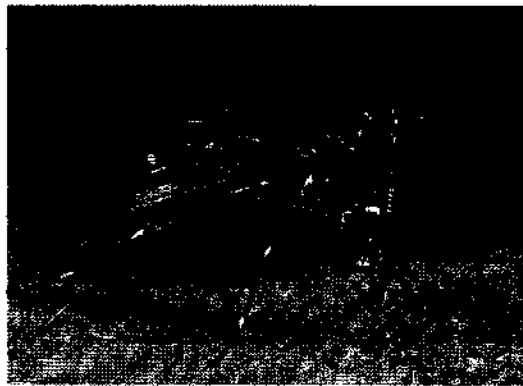
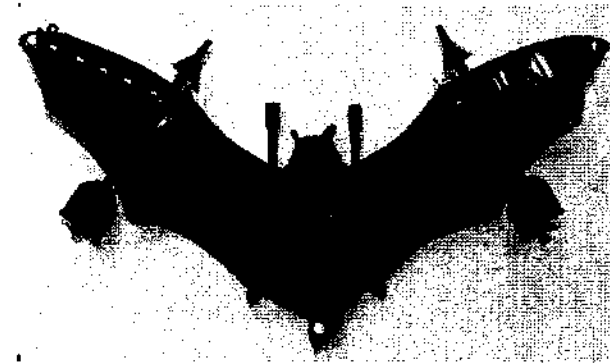
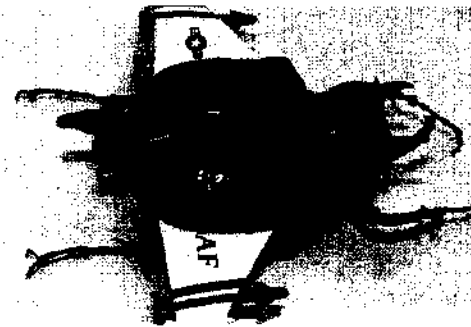
Very Small Weapons, alone Limited Lethality, Mass Attack of Hundreds on Single Target



Biological Machine Weapons – Hybrids?



.....with both biological and artificial (e.g. electronic, mechanical or robotic) parts



....Not quite yet, but surprisingly the work is accelerating.....

Biological Machines - Hybrids



Interfaces between machines and living systems, from individual cells to entire organisms.

Goal is to create novel "biological machines" that *take advantage of living cells' capacity for extremely low-energy yet exquisitely precise movement, communication, and computation.*



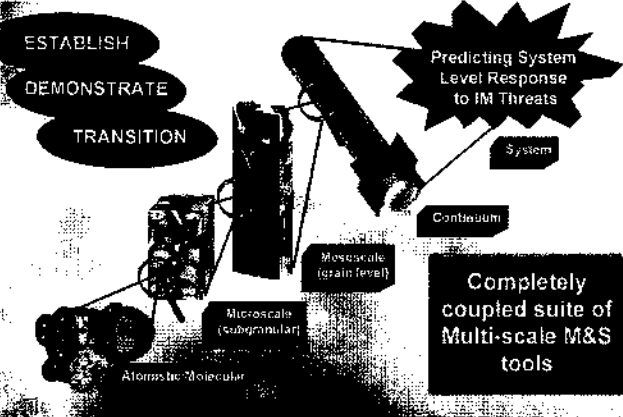
A giant flower beetle with implanted electrodes and a radio receiver on its back can be wirelessly controlled. Scientists at the University of California developed a tiny rig that receives control signals from a nearby computer. Electrical signals delivered via the electrodes command the insect to take off, turn left or right, or hover in midflight.

Could one day be used for surveillance purposes or for search-and-rescue missions and WEAPONS

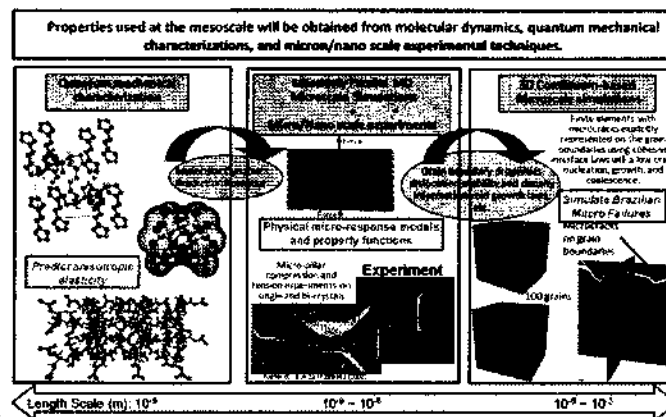
Did anyone say Multi-Scale Modeling & Simulation?



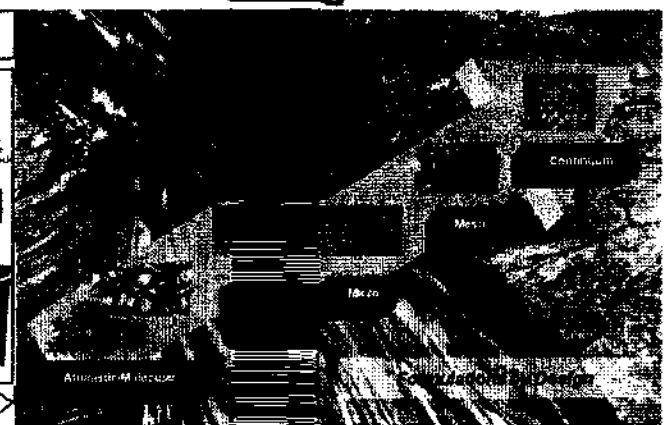
Insensitive Munitions



Ceramics

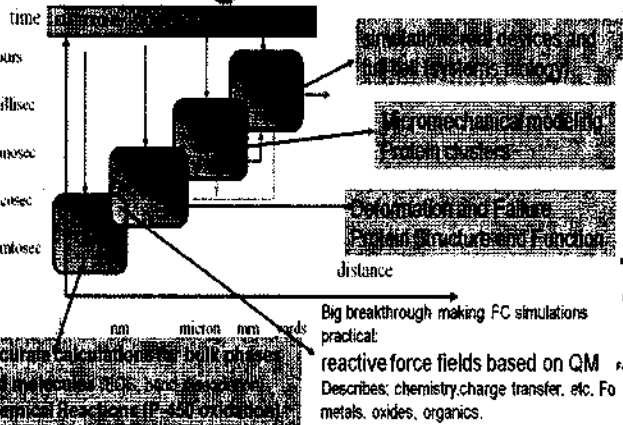


Energetic Materials

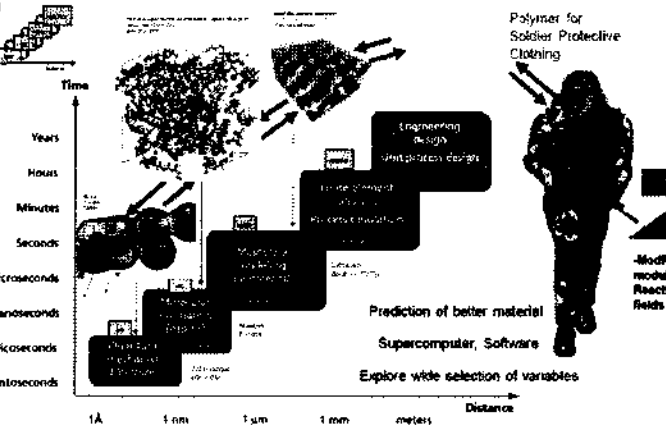


From the bottom up.... *ab-Initio* science that will enable the four dimensional (4-D) spatial & temporal theoretical portrayal of large-scale, complex materials of interest.

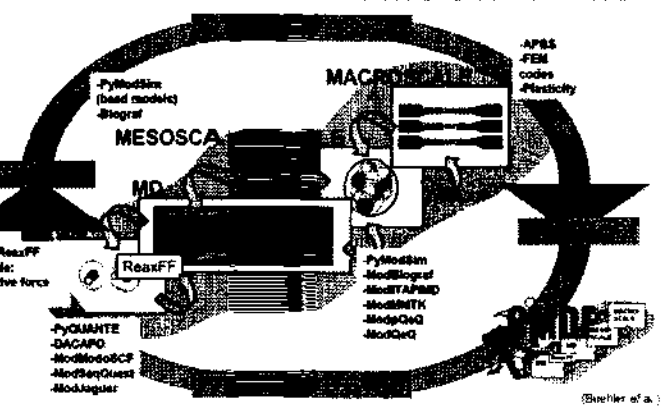
Biological Materials



Multi-Functional Materials



Electronic Materials



How to do this is the Great Debate!

Rating of Technologies



- **Technologies were rated based on “Level of Interest” and previously existing “Funded Program”**
 - **Level of Interest**
 - **Rated by Australia, Canada, UK, US Army, US Air Force, US Navy**
 - **High, Medium, Low, No (Max 18 pts)**
 - **Funded Program**
 - **Rated by Australia, Canada, US Army, US Air Force, US Navy (not UK)**
 - **Yes, Low, Planned, No (Max 15 pts)**
- **Some statistics**
 - **Based on “Level of Interest”**
 - **74 tied for 1st place (18 pts)**
 - **28 tied for 2nd place (17)**
 - **Based on existing “Funded Program” (No input from the UK)**
 - **7 tied for 1st place (15)**
 - **8 tied for 2nd place (14)**
- **Rating does not provide sufficient discrimination for recommended collaboration – general guidance**

Example of Rating Based on Level of Interest



Topic	Ranking	Rating	TRL	Level of Interest					
				Rating:		High	Low	No	
				National Input					
				Australia	Canada	UK	USAF	US Army	US Navy
Directed Energy Weapons & Technology									
Laser Technologies	1	18		High	High	High	High	High	High
High Energy - High Power Lasers	2	17	4	High	High	High	High	High	High
Solid-State Lasers	2	17	2	High	High	High	High	High	High
Fiber Lasers	1	18	5	High	High	High	High	High	High
Free Electron Lasers	5	14	3	High	High	TBD	High	High	High
Attosecond Lasers	9	10	1	Low	TBD	TBD	High	High	TBD
Plastic Dye Rod Lasers	8	11	6	High	TBD	TBD	High	High	TBD
Explosively Pumped Lasers	9	10	2	Low	High	TBD	TBD	High	Low
SPASER Nano-Laser	8	11	1	Low	High	TBD	TBD	High	TBD
Bending Laser Light	4	15	1	High	High	TBD	High	High	High
Laser Guided Energy	1	18	2	High	High	High	High	High	High
High -Power Microwaves (small)	1	18	2	High	High	High	High	High	High
Physics	9	10				High		High	TBD
Bose-Einstein Condensates	8	11	1	Low	TBD	Low	TBD	High	TBD
Electromagnetic Weapons	5	14			High	High		High	High
Electromagnetic Pulse	3	16			High	High		High	High
Nuclear	10	9	9	Low	Low	TBD	Low	High	Low
Conventional Tactical	4	15	1-5	TBD	Low	High	High	High	High
Explosively pumped flux compression generator	3	16		TBD	High	TBD	High	High	High
Explosive and propellant driven Magneto-Hydrodynamic generator	6	13		TBD	TBD	TBD	High	High	Low
Detonation Merging	6	13		Low	High	TBD	High	High	High
Compressed Magnetic Flux - Magneto Hydrodynamic Explosive Munition	5	14		Low	TBD	TBD	High	High	High
High power microwave devices	1	18		High	High	High	High	High	High
Compact EMP weapons	1	18		High	High	High	High	High	High
Electromagnetic kinetic energy devices	7	12	3-5	Low	High	TBD	TBD	High	High
Power generation and storage	1	18	2-4	High	High	High	High	High	High
Atmospheric propagation	1	18	2-7	High	High	High	High	High	High
Thermal management	1	18	2-7	High	High	High	High	High	High
High Speed Weapons (MACH 5+)	1	18		High	High	High	High	High	High
Fuzing	1	18	1-2	High	High	High	High	High	High
Materials	1	18	2-9	High	High	High	High	High	High
Radomes	1	18	1-3	High	High	High	High	High	High
Sensors	1	18	2-4	High	High	High	High	High	High
Propulsion	1	18	3-6	High	High	High	High	High	High
GNC	1	18	2-5	High	High	High	High	High	High
Thermal Management	1	18	2-7	High	High	High	High	High	High
Boosters	1	18	3-8	High	High	High	High	High	High

Example of Rating Based on Level of Funding



Topic	Funded Program								
	Ranking	Rating	TRL	Rating: Yes No					
				National Input					
				Australia	Canada	UK	USAF	US Army	US Navy
Directed Energy Weapons & Technology									
Laser Technologies	2	14		Yes	Yes		Yes		Yes
High Energy - High Power Lasers	4	12	4	No	Yes		Yes	Yes	Yes
Solid-State Lasers	5	11	2		No		Yes	Yes	Yes
Fiber Lasers	2	14	5	Yes	Yes		Yes	Yes	
Free Electron Lasers	10	6	3	No	No		Yes	No	Yes
Attosecond Lasers	13	3	1	No	No		Yes	No	
Plastic Dye Rod Lasers	13	3	6	No	No		Yes	No	No
Explosively Pumped Lasers	13	3	2	No	No		Yes	No	No
SPASER Nano-Laser	13	3	1	No	No		Yes	No	
Bending Laser Light	10	6	1	No	No		Yes	No	Yes
Laser Guided Energy	7	9	2	No	Yes		Yes	Yes	
High -Power Microwaves (small)	5	11	2		No		Yes	Yes	Yes
Physics	10	6			No		Yes	Yes	TBD
Bose-Einstein Condensates	10	6	1	No	No		Yes	Yes	TBD
Electromagnetic Weapons	7	9		No	No		Yes	Yes	Yes
Electromagnetic Pulse	5	11			No		Yes	Yes	Yes
Nuclear	10	6	9	No	No		Yes	Yes	No
Conventional Tactical	7	9	1-5	No	No		Yes	Yes	Yes
Explosively pumped flux compression generator	13	3		No	No		No	Yes	TBD
Explosive and propellant driven Magneto-Hydrodynamic generator	13	3		No	No		No	Yes	TBD
Detonation Merging	7	9		No	No		Yes	Yes	Yes
Compressed Magnetic Flux - Magneto Hydrodynamic Explosive Munition	13	3		No	No		No	Yes	TBD
High power microwave devices	8	8			No		Yes	Yes	TBD
Compact EMP weapons	8	8			No		No	Yes	Yes
Electromagnetic kinetic energy devices	10	6	3-5	No	No		No	Yes	Yes
Power generation and storage	5	11	2-4		No		Yes	Yes	Yes
Atmospheric propagation	7	9	2-7	No	No		Yes	Yes	Yes
Thermal management	7	9	2-7	No	No		Yes	Yes	Yes
High Speed Weapons (MACH 5+)	2	14		Yes			Yes	Yes	Yes
Fuzing	10	6	1-2	No	No		Yes	Yes	TBD
Materials	4	12	2-9	Yes	No		Yes	Yes	Yes
Radomes	7	9	1-3	Yes	No		No	Yes	Yes
Sensors	7	9	2-4	Yes	No		Yes	Yes	No
Propulsion	4	12	3-6	Yes	No		Yes	Yes	Yes
GNC	4	12	2-5	Yes	No		Yes	Yes	Yes
Thermal Management	7	9	2-7	Yes	No		Yes	Yes	TBD
Boosters	10	6	3-8	Yes	No		No	Yes	No

Combined Rating (1/8)



Topic	Ranking		TRL
	Level of Interest	Level of Funding	
Directed Energy Weapons & Technology			
Laser Technologies	1	2	
High Energy - High Power Lasers	2	4	4
Solid-State Lasers	2	5	2
Fiber Lasers	1	2	5
Free Electron Lasers	5	10	3
Attosecond Lasers	9	13	1
Plastic Dye Rod Lasers	8	13	6
Explosively Pumped Lasers	9	13	2
SPASER Nano-Laser	8	13	1
Bending Laser Light	4	10	1
Laser Guided Energy	1	7	2
High -Power Microwaves (small)	1	5	2
Physics	9	10	
Bose-Einstein Condensates	8	10	1
Electromagnetic Weapons	5	7	
Electromagnetic Pulse	3	5	
Nuclear	10	10	9
Conventional Tactical	4	7	1-5
Explosively pumped flux compression generator	3	13	
Explosive and propellant driven Magneto-Hydrodynamic generator	6	13	
Detonation Merging	6	7	
Compressed Magnetic Flux - Magneto Hydrodynamic Explosive Munition	5	13	
High power microwave devices	1	8	
Compact EMP weapons	1	8	
Electromagnetic kinetic energy devices	7	10	3-5
Power generation and storage	1	5	2-4
Atmospheric propagation	1	7	2-7
Thermal management	1	7	2-7
High Speed Weapons (MACH 5+)	1	2	
Fuzing	1	10	1-2
Materials	1	4	2-9
Radomes	1	7	1-3
Sensors	1	7	2-4
Propulsion	1	4	3-6
GNC	1	4	2-5
Thermal Management	1	7	2-7
Boosters	1	10	3-8

Combined Rating (2/8)



Topic	Ranking		TRL
	Level of Interest	Level of Funding	
Micro-Weapons / Munitions & Swarming Multi-Agent Systems	2	3	
Swarming weapons and munitions	2	6	1-2
Direct operator control	5	11	
Teleoperator control	4	8	
Limited control	2	6	
No direct control	5	9	
MEMS based	4	8	1-4
Gun launched, projectile dispersed smart sub munitions	4	6	5
Micro-munitions (self-propelled)	3	8	1
Small Caliber Guided Munitions (< 20 mm)	2	10	2
Medium Caliber Guided Munitions (< 100 mm)	3	14	4
Swarming bullets and sub-munitions	3	10	1-2
Networks	1	3	2-3
Loitering Weapons	5	7	
Transformable weapons	3	10	1-2
"Perching" weapons	5	12	1-2
Maritime loitering	10	13	2-9
Militarization of Space (Space-Based Weapons)			
Space based anti-satellite and anti-missile systems	11	13	3
Space based ground attack systems	11	13	3
Ground based anti-satellite and anti-missile systems	6	11	7
Active Protection			
Point (individual platform)	1	1	2-5
Area (encampment/battle group)	1	1	2-9
Theater (BMD)	2	5	7-9
Environmental Weapons			
Environmental manipulation	11	0	2
Tailoring of weather patterns	11	0	2
High Frequency Active Auroral Research Program	12	0	3
Scalar electromagnetic waves/weapons	12	0	3

Combined Rating (3/8)



Topic	Ranking		TRL
	Level of Interest	Level of Funding	
Non-Lethal / Less than Lethal			
Disruption of power grids	5	14	6
Mechanical Entanglements	9	14	4
Slime, Goo, Grey Goo, Foams	10	14	3
Scalable Enhanced Blast	1	7	5
Reactive Metals, Thermite Warheads and Bombs	4	7	6
Super Lubricants	10	13	3
Corrosive Materials	12	14	4
Engine Disrupters and Combustion Inhibitors	4	12	4
Obscurants	3	9	5
Electromagnetics	3	9	6
Electrical Incapacitating Devices	5	12	6
High-Power Microwaves	3	6	7
Melodorants	12	14	3
Calmatives	12	14	2
Irritants	10	14	5
Flash-Bang	4	12	6
Taggants to Mark Targets	8	14	3
Blunt Projectiles	6	12	4
Laser-Induced Biological Effects	8	12	4
Laser Dazzler	3	8	5
Laser heating	6	10	8
Laser Photochemical Effects	9	11	
Laser Guided Energy / Laser Plasma Channels	10	10	5
Acoustics	7	14	8
Noise and Sound Generators	4	14	4
Sonic Bullets and Magnetic Acoustic Devices	8	0	5
Infrasonic Low Frequency Devices	9	13	4
Mosquito High-Frequency Devices	10	0	4
Electroponic Sound	9	0	6
Bio-Effects and Neuroscience	11	0	3
Tuned Electromagnetic or Other Radiation Sources	7	13	3
Neuroreceptor Targeting Agents	12	0	4
Psychologically Targeted Acoustic Weapons	10	0	3
Visual	9	0	
Laser-Based Holographic Image Projection	11	13	3
Genetically Specific Targeted Effectors	13	0	

Combined Rating (4/8)



Topic	Ranking		TRL
	Level of Interest	Level of Funding	
Fundamental Understanding/Basic Research			
Nano-Structured Materials	2	5	
Nano-Metals (other than Aluminum)	3	3	2-3
Nano Aluminum	4	3	3-9
Nano-Energetics	2	5	3
Nano-Engineered Energetics	3	8	2
Nanoscale Thermite Materials	3	10	2-4
Nano-Porous Silicon	4	11	1-2
Graphene	2	10	1-2
Material studies	2	7	
Weapons applications	3	10	
Fuel catalyst	6	13	
Nano-diamonds	8	13	2-6
Super atom clusters	5	13	1
Coulomb explosions in nano-clusters	7	11	1
Processing and Fabrication	8	8	
Technologies for large volume production	7	13	2-9
Alternate Methods	10	13	2-6
Arrested Reactive Milling (ARM)	8	13	
Energy Saturated Media (ESM)	10	13	
Swaging	10	13	
Metamaterials	2	14	1-3
Nano-Technology Weapons	10	15	1
Nano-molecular manufacturing of weapons	7	0	
Nano-wire obstacles	11	0	
Nano-tipped and/or coated projectiles	9	0	
Nano-fragmenting projectiles and explosively launched fragments	7	13	
Nano-metal warheads for MOUT	8	0	
Nano-edged cutting weapons	8	0	
Novel Physics			
Metastable clusters	4	10	
Polymeric Nitrogen	5	13	1-3
Metallic Hydrogen	7	13	1
Structural Bond Energy Release in Strained Solids	6	13	2-4
Non-fusion ignition of sub-atomic reactions	7	13	1-2
Ballotechnics	9	13	3
New materials formed at extreme pressure	6	13	1-4
Polymeric Carbon Monoxide	7	13	2-3
Nuclear Spin Isomers	7	0	1-2
Anti-Matter	9	13	1
Atomic Propellants	12	0	1
Casimir effect gimbals/gyro	10	11	1

Combined Rating (5/8)



Topic	Ranking		TRL
	Level of Interest	Level of Funding	
Fundamental Understanding/Basic Research (cont'd)			
Multidisciplinary Computational Science	5	9	2
Coupled materials/electrodynamics/chemistry	7	11	
Algorithms for coupling multidisciplinary physics	5	10	
New Experimental methods for Verification and Validation of Multidisciplinary physics	5	9	
Multidisciplinary data management/correlation/output	5	9	
Multidisciplinary visualization	6	9	
Multiscale Material Science	3	11	2
Algorithms for bridging material scales (including energetics)	2	11	
New Experimental methods for Verification and Validation of at and across multiple scales	3	11	
Multiscale data management/correlation/output	3	11	
Multiscale visualization	4	11	
Cold Fusion/LENR	8	14	2-3
Energetic Materials			
New energetic ingredients	1	3	
Fuels, oxidizers, binders, plasticizers, additives	1	3	1-5
Alane (AlH ₃ - replacing aluminum)	5	14	3
ADN (replacing ammonium perchlorate)	6	14	
Encapsulation and doping CNTs as energetic materials	4	8	2-3
Solid gun and rocket propellants	1	2	2-6
Liquid and gel rocket propellant	4	10	2-4
Explosives	1	2	2-6
Enhanced blast, fuel-air, and multi-phase blast explosives	1	5	3-9
Reactive explosive clusters	5	11	3-4
Novel metal complex explosives	4	14	2-6
Reactive materials	3	5	3-4
Penetrating energetic materials	4	8	
Non-penetrating energetic materials	4	7	
Structural energetic materials	5	9	
Biosynthesis of energetic ingredients	7	0	2
Drivers			
Insensitivity	2	1	2-6
Green-toxicity	3	5	2-4
Improved performance	1	2	2-9
Low signature and smoke	3	8	2-9
Cost	5	8	2-9
Systems level energy management (how distribution of energy use in the kill chain influences effect)	4	6	3-9

Combined Rating (6/8)



Topic	Ranking		TRL
	Level of Interest	Level of Funding	
Propulsion			
High-Speed Weapons	16	13	
Ramjets	2	8	3-9
Ducted rockets	2	8	3-9
Scramjets	3	7	3-6
Dual Combustion Ramjets	5	14	5
PDE/PDRE	4	13	3-6
Undersea Propulsion	8	11	
High-speed supercavitating rocket-propelled torpedo	11	0	3
Novel Propulsion	0		
Magnetohydrodynamic augmented propulsion	10	13	3
Hypersonic MHD bypass propulsion	10	0	3
Blast wave accelerator	11	0	2
Laser driven propulsion	11	13	2
Ablative laser propulsion	12	0	
Pulsed plasma propulsion	12	13	
Electro-thermal chemical propulsion	12	0	5
Electromagnetic guns (rail gun)	9	13	4
Payloads			
Blast Warheads	1	4	
Thermobaric explosives	1	5	4-9
Fuel-Air explosives	3	10	4-9
Conventional	5	10	
Energy managed approaches	2	10	2-3
Destruction of chem/bio	5	10	2-6
Penetrators	3	7	
Barrier blind bullets	3	10	3-9
Vehicle and body armor	1	7	2-9
Bunkers and structures	1	7	3-9
CCM	1	7	
Defeat of active protection	1	7	5
Kinetic Warheads	3	7	
Replacements for DU/W	6	10	3-5
Selectable output	13	13	

Combined Rating (7/8)



Topic	Ranking		TRL
	Level of Interest	Level of Funding	
Guidance and Control			
Actuation	1	3	
Adaptive flow control	1	11	5
Plasma flow control	2	13	1
Electro-active polymers	2	13	1
Magneto-rheological fluidic (MR)	1	0	1
Electro-rheological fluidic (ER)	1	0	1
Multi-equilibrium structures	3	13	2
Micro-thrusters	2	5	4
Sensors	1	4	
Advanced photovoltaics (COTS+)	1	10	2-6
Light enhancement for optical systems	1	13	2-3
Multifunctional structures	1	13	1-3
Miniaturized radar	1	13	2
Hyperspectral sensors	1	5	2
LADAR/LIDAR	1	5	2-6
Data fusion between sensors	1	5	3-5
Micro active UWB radar array	1	0	1-2
Chem/bio	2	0	1-2
BDA	3	7	1-4
Algorithms	1	1	
Hardware capable of handling emerging computational requirements	2	4	1-3
Self-contained hardware	3	5	
Massively parallel	4	4	
Advanced electronics (nano-technology, nano-electronics, molecular electronics ...)	2	7	
Software	1	1	
Advanced Flight Controls	1	2	2-5
Bio-inspired algorithms	2	2	1-4
Neuroscience inspired algorithms	3	8	1-3
Reduced State Guidance	1	10	3-5
Magnetic Navigation	6	10	5
Navigation in GPS denied environments	1	2	1-5
Real time navigation initialization	2	11	2-3
ATR	1	3	2-5
Signal Processing - real-time for swarms	1	5	2-4
Autonomy	1	4	2-4
Navigation	1	5	
MEMS Atomic Clock	6	13	2
Power	1	1	
Energy harvesting	1	11	2-3
Power sources - long duration and/or miniature	1	4	2-4
Nano electronics	4	13	1-2
Nano radios/antennae	4	0	2-3

Combined Rating (8/8)



Topic	Ranking		TRL
	Level of interest	Level of Funding	
Fuzing	2	4	
Sensors	4	10	
Impact-sensor for adaptive fuzing	4	10	1-3
Thin film magnetometers	5	0	1-2
Seeker integrated fuzing	1	7	2-5
Multi-point initiation	13	13	
Materials and Structures			
Nano-composites		7	3-6
Carbon Nanotubes (CNTs)	1	7	2-5
Novel alloys	2	7	1-7
Bulk metallic glass	1	10	1-2
Ceramics	3	7	1-7
Composites/hybrids	1	5	1-9
Multi-functional	1	7	1-9
Coatings	1	4	1-9
Polymers/plastics	1	7	1-9
Low observables	2	5	1-9
Morphing materials	1	10	2-6
	1		
Supporting Technologies			
HWIL/Scene generation		5	2-9
Database of scenes/maps/clutter (multi-spectral)	1	7	2-9
Projectiles	1	10	2-4
High fidelity M&S	3	1	3-9
	1		
Environmental			
High g launch		7	3-9
Temperature	1	4	
Aeroheating from high speed	1	4	3-9
	1		

Preliminary Recommendations (1/5)



Process

- **There is a need for an annual ongoing assessment of novel weapons technologies including their military potential, and their probable effect on future warfare. Implementation options include:**
 - **Focus Group – a new way of doing business requiring a dedicated team**
 - **A new WPN Technical Panel**
 - **An ad hoc panel brought together annually from members across the WPN Technical Panels**
- **A structured methodology needs to be adopted, potentially based on the work to be done by TTCP JSA AG 17**

Preliminary Recommendations (2/5)



Collaborations

- Providing a short list of collaborations was challenging due to the large number of technologies identified in the Deep Dive
- The proposed approach for generating a short list involves *two basic categories* for collaboration, *broad technology areas* and *specific technologies*
- Each category can be subdivided into *two time frames*, immediate and longer term
- *Immediate implementation* would be for broad technology areas and specific technologies where there is *both strong interest and funding*
- *Longer term implementation* would be for broad technology areas and specific technologies where there is *strong interest but lower funding levels*

Preliminary Recommendations (3/5)



Identifying Collaborations (cont'd)

- **Broad technology areas that have been identified for immediate implementation would be turned over to new AG's**
- **Broad technology areas with longer term implementation, a new entity would be created at the WPN level - Focus Group – for technology watch**
- **Specific technology areas would be delegated to TP's whether for immediate or longer term implementation**

Broad Technology Areas			
Now		Watch	
Technology Area	Action	Technology Area	Action
Laser weapons	AG	High Powered Microwave weapons	Focus Group
Active protection	AG	Micro weapons	Focus Group
		Weapon autonomy	Focus Group
		Swarming weapons	Focus Group
		High fidelity M&S	Focus Group

Specific Technologies			
Now		Watch	
Technology Area	Action	Technology Area	Action
Ingredients for EM	TP 4	Reactive materials	TP 4
GNC algorithms	TP 7	Advanced sensors	TP 7
Navigation in GPS denied environments	TP 7	Automatic Target Recognition	TP 7
		Adaptive flow control	TP 2
		Scalable enhanced blast	TP 1, 4

Preliminary Recommendations (4/5)



Broad Technology Areas			
Now		Watch	
Technology Area	Action	Technology Area	Action
Laser weapons	AG - To cover non-lethal to lethal (need to write terms of reference)	High Powered Microwave weapons	Focus Group - Evaluate interest and funding of all technologies identified across countries on an annual basis. Encourage funding if deemed reasonable.
Active protection	AG - Covers several Groups (WPN, SEN and MAT) and TPs (WPN TP 1, 4). Also is multi-environment, land, air and sea.	Micro weapons	Focus Group - as above
		Weapon autonomy	Focus Group - as above
		Swarming weapons	Focus Group - as above
		High fidelity M&S	Focus Group - To access across WPN what is being done, evaluate what is the potential including, corresponding interests (type of modelling) and what are the constraints on collaboration, determine if there is sufficient interest and funding and whether interests are compatible. The FG would last one year with effort then be transferred to TPs. This technology area could provide significant cost reduction through minimizing experimental testing.

Preliminary Recommendations (5/5)



Specific Technologies			
Now		Watch	
Technology Area	Action	Technology Area	Action
Ingredients for EM	TP 4	Reactive materials	TP 4
GNC algorithms	TP 7	Advanced sensors	TP 7
Navigation in GPS denied environments	TP 7 - Might be overtaken by a workshop. This is already a Focus Group in TP 7 and needs to consider a higher level of activity.	Automatic Target Recognition	TP 7
		Adaptive flow control	TP 2
		Scalable enhanced blast	TP 1, 4

Summary of Future Activities



- **Finalize recommendations and report**
- **Deliver report – present objective is end of March 12**

Action Items from WPN Group



- **Create a new TP (TP-9) Novel Weapons Technologies**
 - **The AG-25 proposed 'new AGs' would become the first KTAs of TP-9**
 - **Items proposed by AG-25 for the watch list could become focus areas for TP-9**
- **AG-25 to prepare a draft TOR for TP-9**
- **AG-25 to identify proposed representatives and possible chair of TP-9**

The proposal to create TP-9 was not approved by the TTCP principals



Questions?