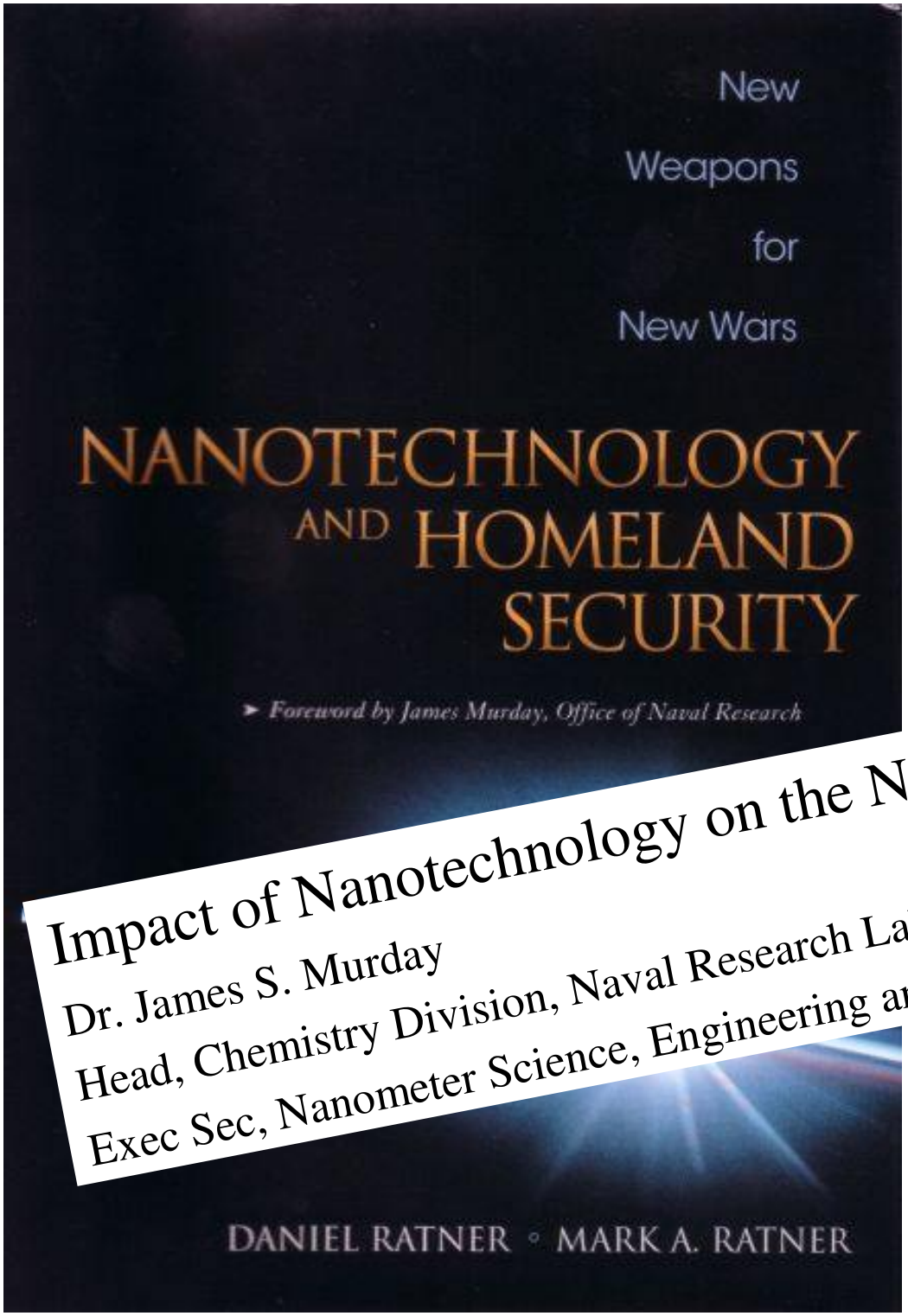
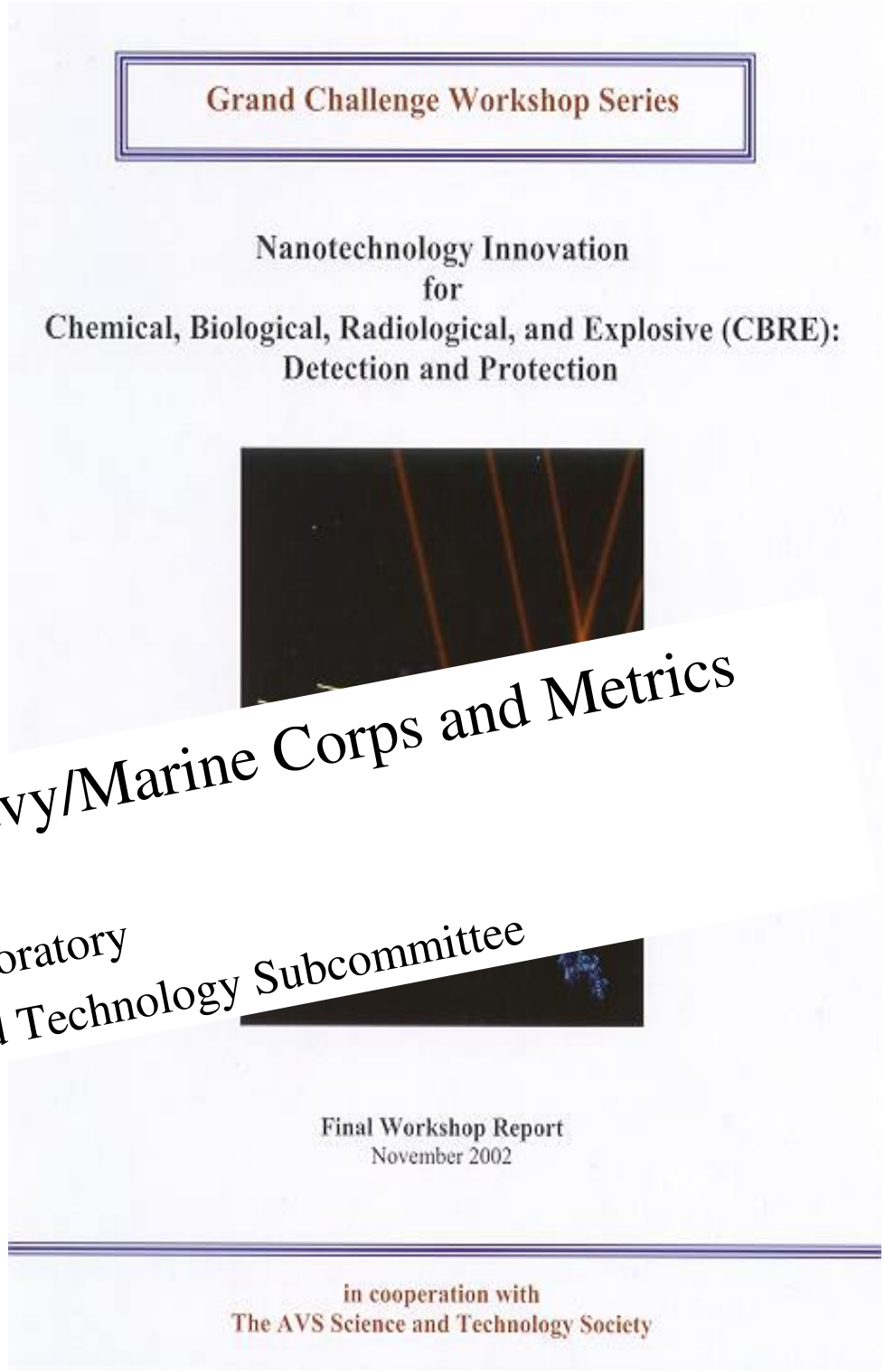
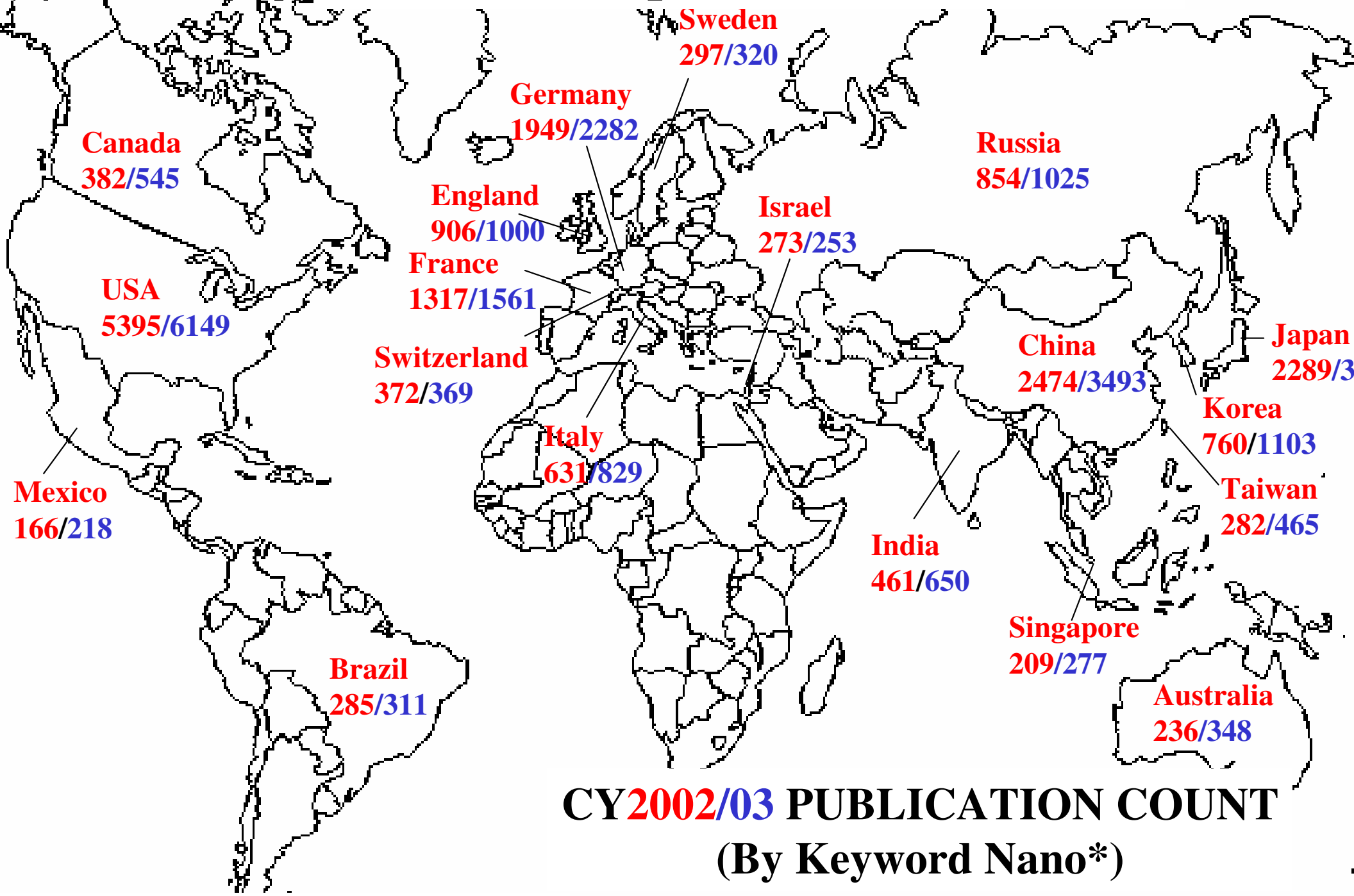
Impact of Nanotechnology on the Navy/Marine Corps and Metrics

Dr. James S. Murday
Head, Chemistry Division, Naval Research Laboratory
Exec Sec, Nanometer Science, Engineering and Technology Subcommittee





Global Participation in Nanoscience



CY2002/03 PUBLICATION COUNT
(By Keyword Nano*)

Science Citation Index of 5300 Journals

Total Worldwide- **18539 /24208**

Enhanced warfighting capabilities

- **Higher performance information technology**

  Terabit/cm^2 memory, near terahertz logic, non-volatile MRAM,…

- **Persistent, distributed sensing**

  Microfabricated sensory suites, local information processing, low power operation,….

- **Autonomous, uninhabited vehicles**

  Local command/control; miniaturization to reduce payload; increased endurance and range;…

- **Virtual/Augmented reality training**

  Full sensory – oral, visual, tactile; tailored to individual learning modes; ….

- **Individual Warfighter technologies**

  Miniaturization of IT; power supplies; active camouflage;….

- **Chem-bio warfare defense**

  Improved detection sensitivity and selectivity; decontamination; protection; therapeutics;…

- **High performance platforms and weapons**

  Stealth over multiple spectral bands; higher strength, light-weight materials and structures; reduced maintenance,…

- **Energy and energetic materials**

  Fast release explosives; insensitive munitions; slow release propellants,…

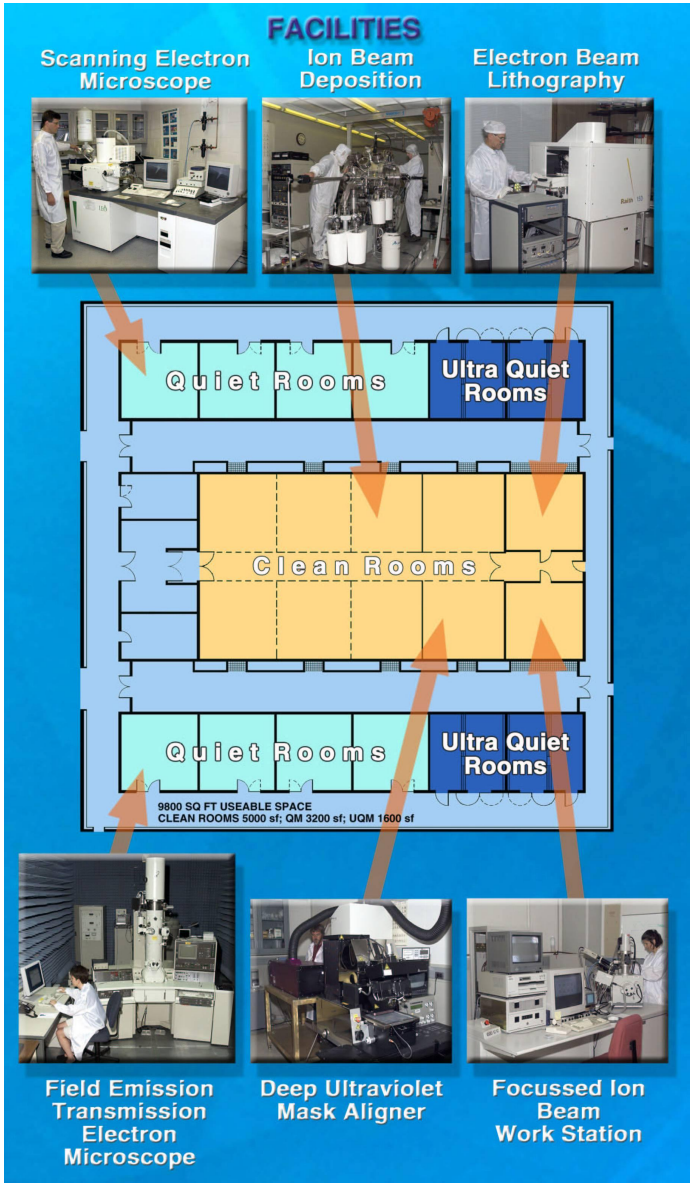
- **Medicine / heath / casualty care**

  Individual status monitors; better sanitary conditions (water, food); wound dressings; prosthetic devices; …

FY2004 Naval Investment in Nanotechnology (~$M)

	6.1	6.2/6.3
Nanomaterials		
Electrical Power and Energy		
Thermoelectric, photoelectric	2.5	
Battery, fuel cell	3.5	
Structural and Functional Materials	5.5	0.5
Environmental	2	
Nano-Electronics, -Photonics, - Magnetics		
Electronics	10	0.5
Photonics	2.5	
Magnetics	3	
Nanobiotechnology	5.5	
Cross cutting	6	
Total	40	1

NRL Nanoscience Institute
Facility and Program

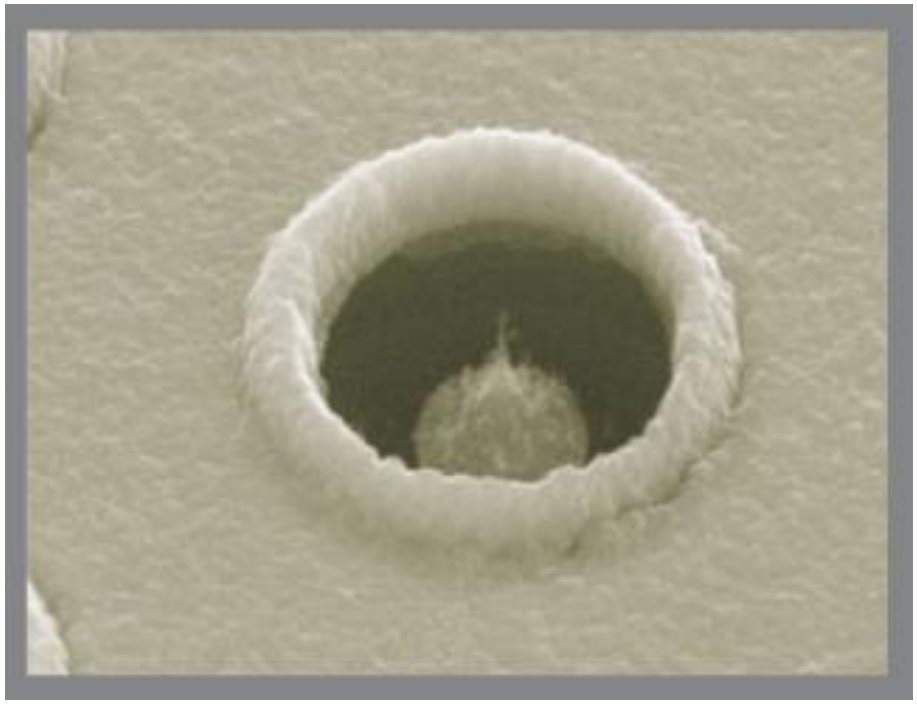


Dr. Gary Prinz, NRL Code 1100

- **Nanoassembly**
  - Nanofilaments: Interactions, Manipulation and Assembly
  - Chemical Assembly of Multifunctional Electronics
  - Directed Self-Assembly of Biologically-Based Nanostructures
  - Template-Directed Molecular Imprinting
  - Chemical Templates for Nanocluster Assembly
- **Nano-optics**
  - Photonic Bandgap Materials
  - Org. and Bio. Conjugated Luminescent Quantum Dots
  - Organic Light Emitting Materials & Devices
  - Nanoscale-Enhanced Processes in a Quantum Dot Structures
- **Nanochemistry**
  - Functionalized Dendrimeric Materials
  - Polymers and Supramolecules for Devices
- **Nanoelectronics**
  - Coherence, Correlation and Control in Nanostructures
  - Neural-Electronic Interfaces
- **Nanomechanics**
  - Nano-Elastic Dynamics
- **Collaborations**
  - Developing with universities, NSWC Indian Head, ARL Adelphi, NAVAIR

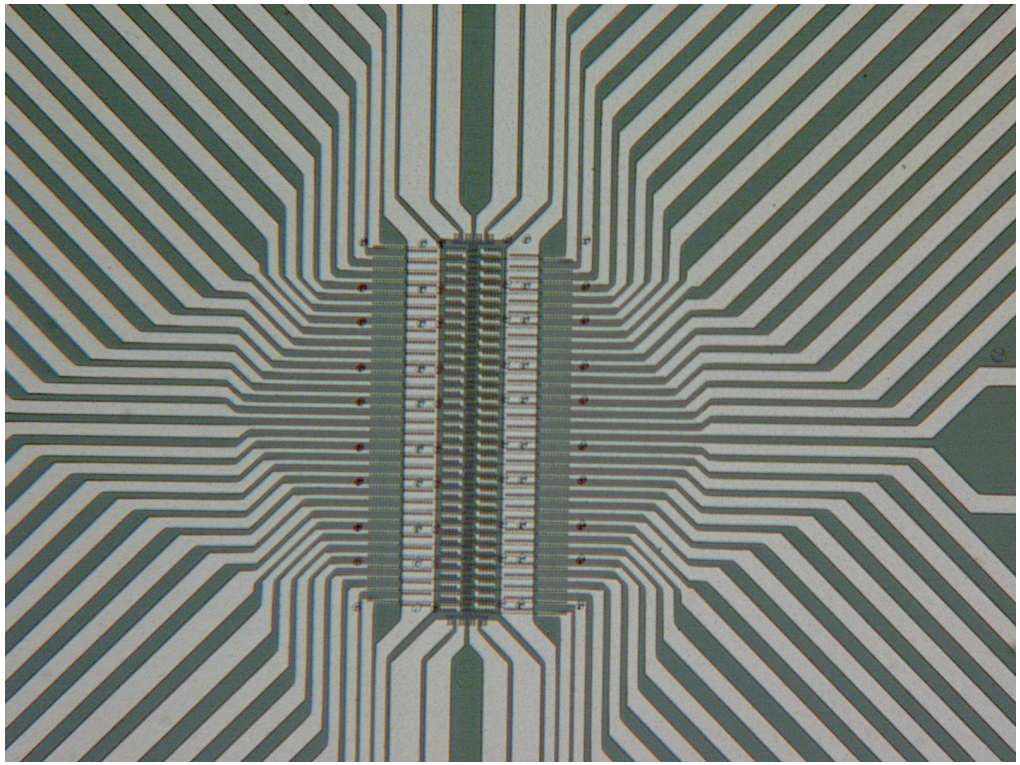
http://nanoscience.nrl.navy.mil/

Nanotube Field Emitter Array



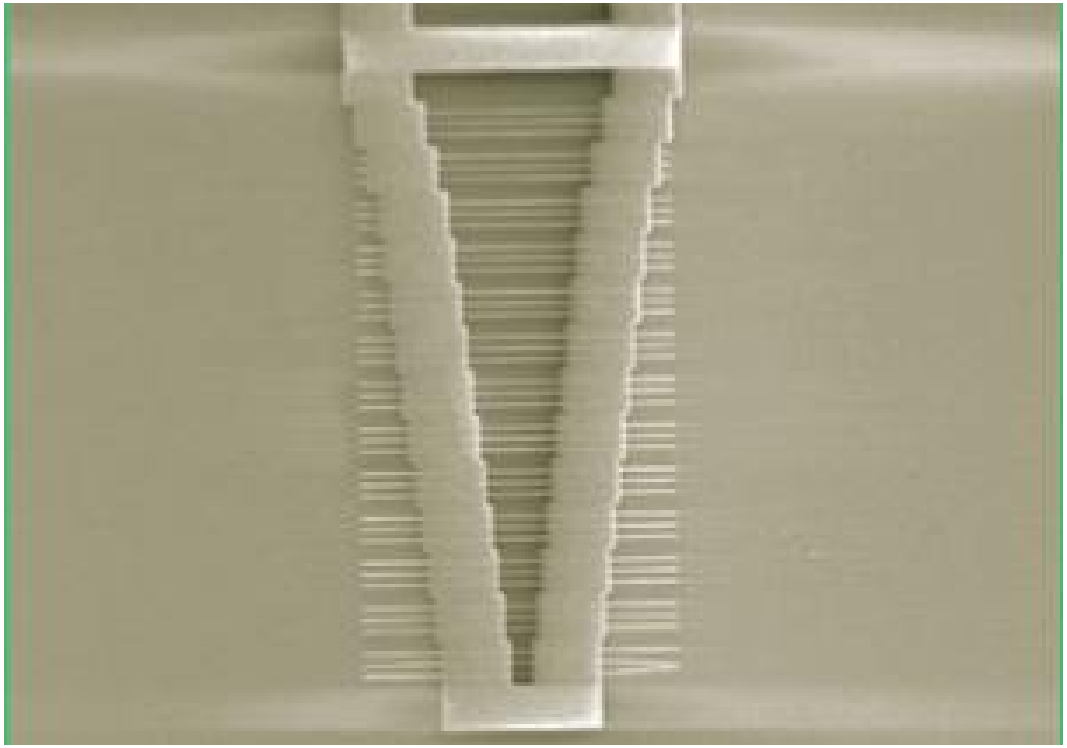
Nanotube "cold'cathode" devices have demonstrated very low voltage, high current density, and exceptional robustness, enabling many potential applications, such as radio frequency amplifiers for communication and radar, electric propulsion for microsatellites, sunlight readable flat panel displays, and portable x-ray sources for field medical and security diagnostics.

High Density Nonvolatile Memory



Magnetoelectronic ring elements (600 nm diameter) store digital information at a density of 100 Gbits/in^2 on computer memory chips. Operating at ns read/write times, information is retained with power off, providing a rugged, compact, low power replacement for disc-drive storage of data for field operations.

Low Power Communications System



Electromechanical oscillators, fabricated from diamond films, provide low power, high frequency operation for communication and signal processing in nanoelectronic systems. Device shown as 80-nm-wide "wires," which oscillate at 1 GHz.

NNI/NSET/NNCO YEAR ONE GPRA, WASHINGTON

This card is a description of your child's development at this time

A (T) indicates the developmental level of your child at this time.

		REPORTING PERIODS						REPORTING PERIODS			
THINKING THROUGH PROBLEMS	works out solutions	T				BEHAVIOR IN	participates with confidence and assurance	T			
	is dependent on help										
	is easily discouraged										
SPEAKING SITUATIONS	expresses ideas and feeli										
	is growing in use of sent						nts of others	T			
	seldom takes part in co						hers				
LISTENING SITUATIONS	listens attentively										
	listens when encouraged					MEETING NEW SITUATIONS	accepts new situations with reasonable ease	T			
	listens with difficulty						becomes upset				
FOLLOWING DIRECTIONS	is reasonably accurate	T				RESPONSE TO RULES	follows rules of group and school	T			
	needs considerable help						cooperates when encouraged				
	works efficiently						disregards group decisions				
	shows initiative and originality	T				REACTION TO	accepts and tries to improve	T			

Fundamental Knowledge
Proposed NNI Metrics

Means (programmatic, activity, immediate)

Adequate and balanced federal S&T funding
Ready availability of fabrication/measurement capabilities
Multidisciplinary programs
Professional Society nanoscience functions
International program collaborations

End (substance, result, productivity, 3-5 year delay)

Papers in refereed journals, especially journals with a high impact factor
Nanoscience papers cited by patents
Patents granted (and licensed) to federally funded S&T
Awards/honors bestowed

NNI/NSET/NNCO YEAR ONE GPRA, WASHINGTON

This card is a description of your child's development at this time

A (T) indicates the developmental level of your child at this time.

		REPORTING PERIODS						REPORTING PERIODS			
THINKING THROUGH PROBLEMS	works out solutions	T				BEHAVIOR IN	participates with confidence and assurance	T			
	is dependent on help						follows others				
	is easily discouraged						pates very little				
SPEAKING SITUATIONS	expresses ideas and feelings						thoughtfulness				
	is growing in use of sentenc						recognizes the rights of others	T			
	seldom takes part in conver						little concern for others				
LISTENING SITUATIONS	listens attentively						s quickly and easily				
	listens when encouraged						s new situations with reasonable ease	T			
	listens with difficulty						es upset				
FOLLOWING DIRECTIONS	is reasonably accurate	T				RESPONSE TO RULES	follows rules of group and school	T			
	needs considerable help						cooperates when encouraged				
WORK HABITS	works efficiently						disregards group decisions				
	shows initiative and originality	T				REACTION TO CORRECTION	accepts and tries to improve	T			
	needs help with planning and following through						needs help in accepting corrections				

Innovative Technology

Proposed NNI Metrics

Means (programmatic, activity, immediate)

Partnerships with industry

Crisp, compelling plans for NNI Grand Challenges

Growing applied research and exploratory development funding by NNI agencies

SBIR/STTR programs and evidence for their transition into commercial product

End (substance, productivity, >5 year delay)

Commercial value of products enabled by nanostructures

Growth of technologies utilizing ever more sophisticated nanostructured systems

Industrial investment in nanoscience and nanotechnology

Professors directly associated with companies commercializing new products

DOD VISIONS POTENTIALLY ENABLED BY NANOTECHNOLOGY

Uninhabited Combat Vehicle - $1K "human" brain – manpower risk reduction

- Rapid (ms) decisions with only "strategic" human intervention
- Full image storage/processing in RF, mm, THz, IR, visual, UV,…
- High g maneuverability, no life support (O_2, CO_2, food)
- High strength/weight, low observable, condition based maintenance, …

Warfighter

- Wearable Personal Information System – augmented reality
- Monitor/actuation system for CBRN, fatigue, casualty
- "Smart uniform" – active camouflage, CB/ballistic protection, local power
- "Smart weapon" – lower weight, automated decision
- Individual genome mediated assignments
- Augmented human performance – cyborg like

Virtual/Augmented Reality Training/Education/(Entertainment)

- 200,000 DOD recruits trained / yr; $1M / yr per pilot to sustain qualifications
- Full oral, visual, tactile interaction – tailored learning modes
- Interactive group involvement
- Electronic "paper" with conformal thin film power source

DoD Programs in Nanotechnology

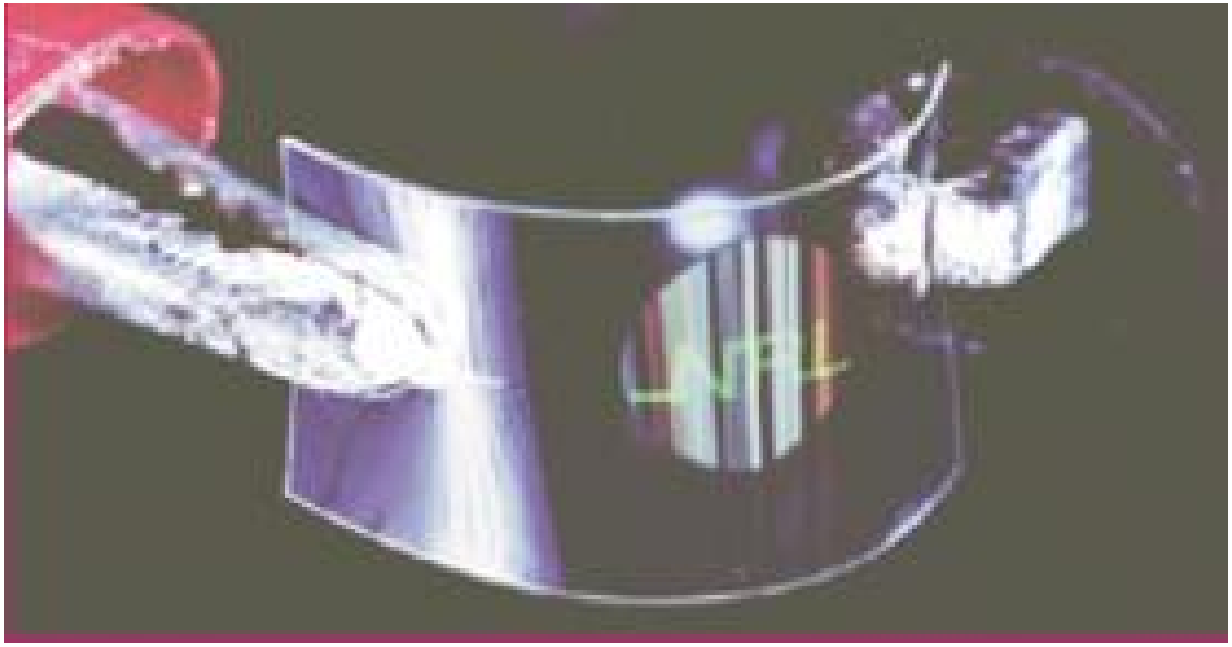
- Army
  Nanostructured polymers, quantum dots for IR sensing, nanoengineered clusters, nano-composites, Institute for Soldier Nanotechnology (ISN)
- Navy
  Nanoelectronics, nanowires and carbon nanotubes, nanostructured materials, ultrafine and thermal barrier nanocoatings, nanobio-materials and processes, nanomagnetics and non-volatile memories, IR transparent nanomaterials, NRL Nanoscience Institute
- Air Force
  Nanostructure devices, nanomaterials by design, nano-bio interfaces, polymer nanocomposites, hybrid inorganic/organic nanomaterials, nanosensors for aerospace applications, nano-energetic particles for explosives and propulsion
- DARPA
  Bio-molecular microsystems, metamaterials, molecular electronics, spin electronics, quantum information sciences, nanoscale mechanical arrays
- MDA
  Budding interest as science matures
- SBIR
  Nanotechnologies, quantum devices, bio-chem decontamination
- MANTECH
- OSD
  Multidisciplinary University Research Initiative (MURI), DEPSCoR, NDSEG

Defense Nanotechnology Research and Development Programs
Report to Congress, April 2004

DoD Nanoscience Funding Summary

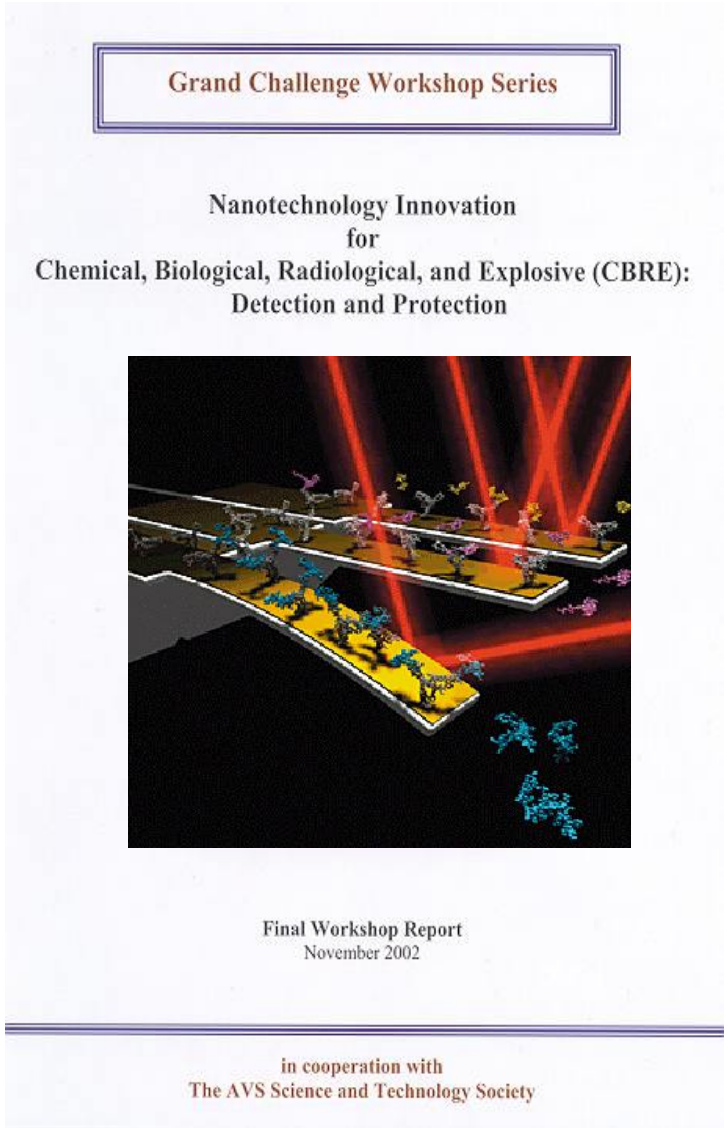
	FY01		FY02		FY03		FY04 (est)		FY05 (req)	
	6.1	6.2/6.3	6.1	6.2/6.3	6.1	6.2/6.3	6.1	6.2/6.3	6.1	6.2/6.3
Air Force	5	3	11	9	9	7	29	7	8	
Army	7	8	18	5	24	15	26	9	25	8
Navy	20	3	38	2	34	1	40	1	40	1
DARPA	34	20	48	66	84	120	65	138	66	98
DDRE	24	2	26	2	28	0	0	0	0	0
Total	153		225		322		315		276	

Molecular Organic Light Emitting Diodes



A promising new nanotechnology is based on ultra-thin (<100nm) organic light-emitting diodes incorporated into flexible, bright, and efficient full-color electronic displays. Applications range from head-mounted micro-displays to large flat panel screens that can be rolled up or hung flat on a wall.

NNI Grand Challenge Workshop



Nanotechnology Innovation

For

Chemical, Biological, Radiological and Explosive: Detection and Protection

Sensing

- Unparalleled sensitivity
- Array based selectivity

Protection

- High surface area materials
- Nanoporous separation

Decontamination

- Highly reactive, catalytic nanostructures

Therapeutics

- Prophylactic nanostructures
- Biological disruption

http://www.wtec.org/nanoreports/cbre/