Materials for Antiterrorism and Other Critical National Needs

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www.nationalacademies.org/nmab

National Research Council

- The 'operating arm' of the National Academies of Science and Engineering
- A non-profit organization established in 1916
- Mission:
  - Surveys the broad possibilities of science, engineering, and medicine
  - Directs the attention of scientific and technical communities to the value of their knowledge to the achievement of national goals
  - Assesses the state of current understanding that helps to illuminate public policy decision making
  - Promotes cooperation in research, at home and abroad
  - Broadly disseminates its works throughout the world

Recent events

- Attacks on September 11 revealed vulnerabilities
  - airplanes
  - buildings
  - scanning and sensing
- Anthrax in US mail added others
  - decontamination
  - forensics
  - scanning and sensing

"Making the Nation Safer"

- "*The role of science and technology in countering terrorism*"
- A study by the National Research Council of the National Academies
- Published July 2002
- www.nap.edu/catalog/10415.html

"Making the Nation Safer"

- Conducted by a distinguished committee
- Eight panels addressed the following:
  - Nuclear and radiological threats
  - Human and agricultural health systems
  - Toxic chemicals and explosive materials
  - Information technology
  - Energy systems
  - Transportation systems
  - Cities and fixed infrastructure
  - The response of people to terrorism

"Making the Nation Safer"

- The report describes some general principles and strategies:
  - Identify and repair the weakest links in vulnerable systems and infrastructures
  - Use defenses-in-depth (do not rely on perimeter defenses or firewalls)
  - Use "circuit breakers" to isolate and stabilize failing system elements
  - Build security into basic system designs where possible
  - Build flexibility into systems so that they can be modified to address unforeseen threats
  - Search for technologies that reduce costs or provide ancillary benefits to civil society to ensure a sustainable effort against terrorist threats

"Making the Nation Safer"

The report names seven "urgent research opportunities":

- Develop effective treatments and preventatives for known pathogens for which current responses are unavailable and for potential emerging pathogens
- Develop, test, and implement an intelligent, adaptive electric-power grid
- Advance the practical utility of data fusion and data mining for intelligent analysis, and enhance information security against cyberattacks

"Making the Nation Safer"

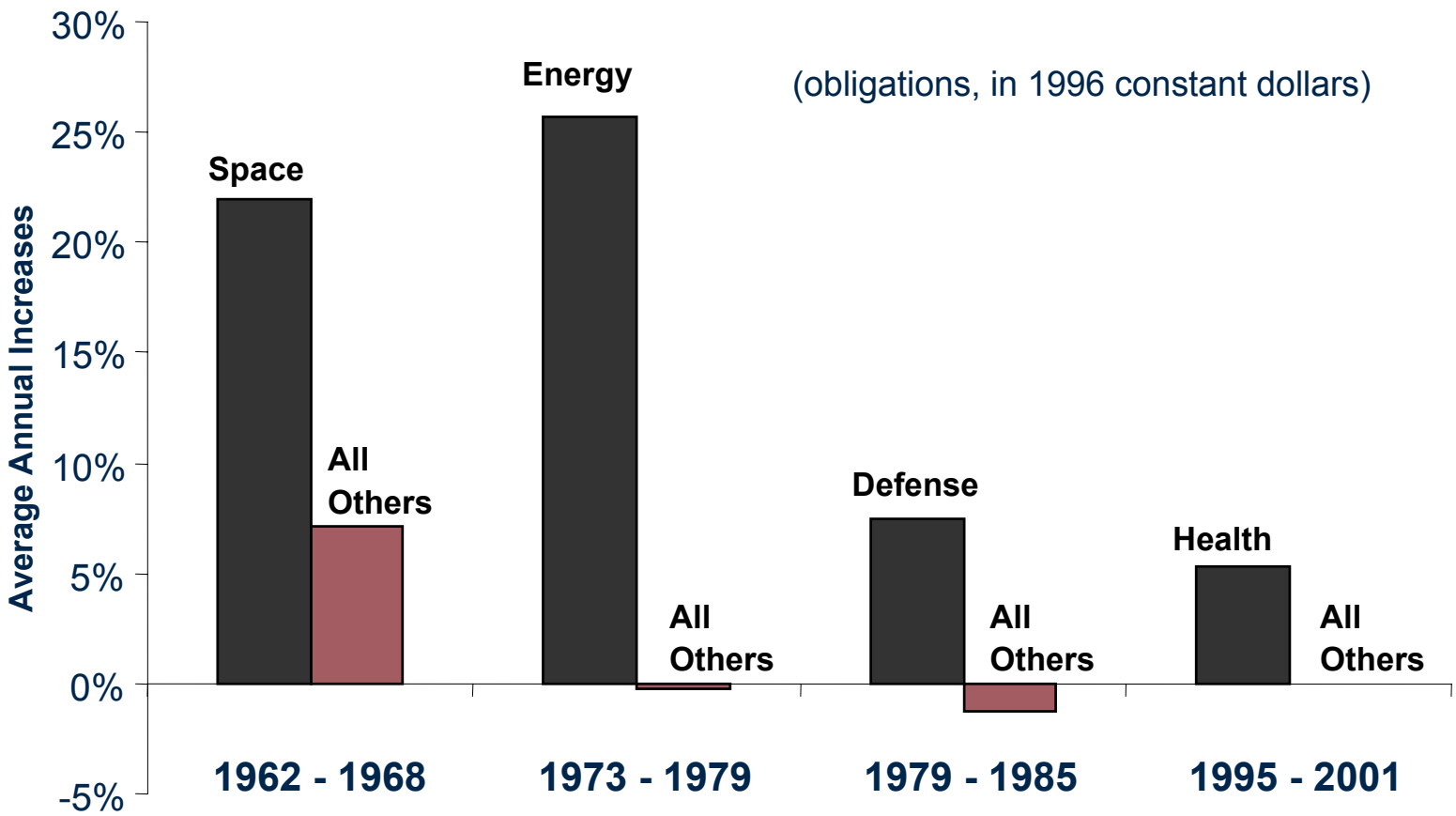
Four of these urgent research opportunities have *a strong focus for materials*

4. Develop new and better technologies (e.g., protective gear, sensors, communications) for emergency responders
5. Advance engineering design technologies and fire-rating standards for blast-and fire-resistant buildings
6. Develop sensor and surveillance systems (for a wide range of targets) that create useful information for emergency officials and decision makers
7. Develop new methods and standards for filtering air against both chemicals and pathogens as well as better methods and standards for decontamination

The role of materials

- Three considerations
  - There are always bigger priorities
  - Research funding is increasingly complex
  - Materials are always part of other systems

Historical R&D Priorities



THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

Source: National Science Foundation

DoD Critical Capabilities

- Protect bases of operations
- Conduct information operations
- Project and sustain US forces
- Deny enemy sanctuary
- Conduct space operations
- Leverage information technologies

DoD major program trends

- Army investment strategy changes
  - FCS & Objective Force related efforts ↑
  - Armor / anti-armor materials ↑
  - Personnel protection ↑
- Air Force investment strategy changes
  - Space ↑
  - Environment →
  - Sensor and photonic materials →
- Navy investment strategy changes
  - Stainless steel ship hulls ↑
  - Composite applications in shore facilities ↑
  - Total Operational Cost projects: corrosion, condition-based maintenance, coatings ↑

More program trends

- Missile Defense Agency technology funding ↓
- Hypervelocity enabling technologies ↑
- Operational support materials and processes integration →
- Active-adaptive “smart” morphing materials demonstrations ↑
- Ultralight weight materials ↑

Near-Term Projections

- Increased funding for defense and defense S&T
- Focus on capabilities versus opportunities or potentialities
- Focus how S&T can help homeland security and homeland defense
- Evolutionary / generational planning and assessment of
  - Capabilities
  - Materiel
  - Science and technology

Immediate antiterrorism needs

- Improve portal security and checkpoint systems
- Address cargo concerns (including US mail)
- Protect critical infrastructure
  - Transit stations
  - Gathering spaces
  - Public utilities

Longer term:

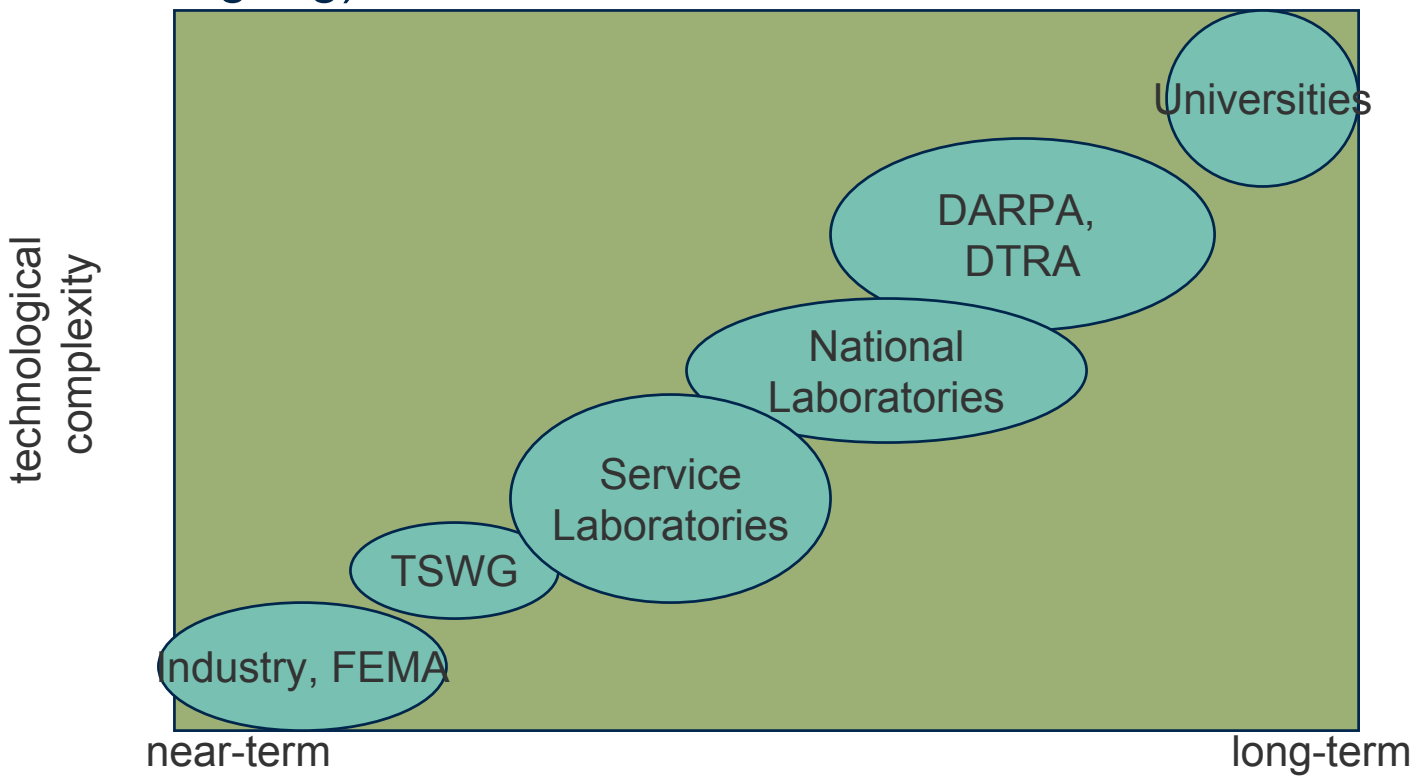
- Decrease cost of materials and manufacturing to improve access and use of technologies
  - Integrate design and manufacture
  - Accelerate materials and process technology insertion
- Create a national strategy for a strong US materials and manufacturing base to support future wartime efforts
  - Maintaining dual supply
  - Maintaining strategic stability of supply
  - Developing functional substitutes
  - Stabilizing domestic supply base

Technology focus

- Preparation and mitigation to reduce vulnerability
  - Chem/bio resistant materials & textiles
  - Integrated protection equipment
  - Low cost and 'wideband' passive sensors
  - Hardening against blast, penetration, fire
  - Characterization schemes for identified threats
- Intelligence support
  - Sensing and imaging to detect potential threats
- Consequence management
  - Schemes for decontamination
- All must be smaller, lighter, lower cost

Technical Support Working Group

- Multiagency group with a focus on technologies for antiterrorism (http://www.tswg.org)



Technical Support Working Group

- 'Top 5' needs for basic research:
  - Stand-off and non-intrusive detection of biological and chemical agents and of explosives
  - Through structure imaging
  - Chem-bio decontamination and chem-bio personal protection equipment
  - Chem-bio forensics
  - Infrastructure network link analysis

Contributions from materials science

- Must provide for affordable systems and operations
  - hundreds of thousands of miles of conduits to monitor or harden
- Changes must enhance both functional and security
  - Integrate sensors into structures to improve awareness
  - Hardened structures should both extend life and enhance reliability, such as self-healing
- Functional substitutes will be needed for security
  - Distributed electricity generation
    - turbines
    - fuel cells
  - Wireless vs wired communication
  - Alternative lubricant and fuels
  - Flexibly-fueled transportation

Transportation security

- Underaddressed requirements
  - Standoff detection of explosives
  - Prerelease chem/bio weapons detection
  - Fast post-release chem/bio weapons detection
  - Explosive detection system efficiency

Standoff Detection of Threats

- Concealed threats
  - Explosives
    - Military plastic or sheet
    - Commercial
    - Black and smokeless powder
    - Improvised devices
    - Advanced energetics
  - Chem/bio weapons
  - Nuclear/Radiological materials

- Standoff Detection and Imaging
  - On persons
  - Inside aircraft baggage
  - Inside vehicles (cars, trucks)
  - Inside cargo containers (air, rail, truck)
  - Inside buildings
  - Under rubble
  - In underground bunkers and tunnels

Bulk detection

- Probing radiation
  - Neutrons
  - Gamma rays
  - Electromagnetic
    - Quadropole resonance
    - Mass spectroscopy
    - Dielectric constant
    - Infrared imaging
- X-rays
  - Computed tomography
  - Backscatter
  - Resonance absorption
  - Transmission
    - High energy
    - Dual energy
  - Diffraction

Need to balance deterrence and effectiveness

Trace explosives detection

- Residues or vapors of explosives
- View optically or activate traces
  - Collect
  - Separate
  - Detect
- Techniques
  - Chemiluminesence
  - Mass spectroscopy
  - Ion mobility spectrometry
  - Canine olfaction
  - Preferential absorption
  - Antibodies
  - Optical techniques

Through-structure imaging

- 'Walls' are made of many different materials in various combinations and configurations
- Must compensate for diffraction, attenuation, and refraction

Through-structure imaging

- Key: characterize the container
  - Walls
  - Containers
  - Rock
- Even better: tailor the container
  - Smart materials
  - Smart structures
  - Integral sensors
- Future: intelligent dust

Chemical and biological defense

Chemical agents - *quick acting*
Biological agent - *slower acting, more difficult to identify*

- Issues
  - Detection
  - Protection
  - Decontamination
  - Agent dispersal modeling

Biosensors detection methods

- Point probes
  - Sequence recognition (ie, nucleic acid): DNA chips
  - Chemical analysis (ie, mass spec)
  - Function (ligand) based (ie, cellular activity): cellular-surface proteins that bind to specific molecules
  - Structure recognition (ie, antibody): immunosensors
- Standoff detection
  - Light
    - IR LIDAR
    - UV laser
    - Detect generic or specific characteristics of an aerosol cloud that indicate a man-made event
- Sampling techniques
  - Impactor
  - Cyclone
  - Bubbler/impinger

Detection system requirements

- Tactical usefulness
  - Man-portable
  - Integral in existing systems
  - Self-powered with low power needs and long life
  - Affordable for law enforcement, prisons, fire departments
  - Maximum standoff
  - Unambiguous display
- Various timescales
  - Some urgent applications (military ops)
  - Some less (law enforcement, hostage rescue)
  - Some not (nuclear power plant mapping)

Advanced energetics

- Focus is in the energy range between conventional energetics and nuclear fission (between 100 and 1000 cal/g)
- Evolutionary and Revolutionary Technologies
  - Shock-dissociated advanced fuels and oxidizers
  - Nanostructured materials
  - Use of reactive materials
  - Advanced CHNO chemistry, including cubanes
  - All/higher nitrogen and hydrogen energetics, including N5+ cations
  - Designer explosives with metallic additives
  - Micro- and metastable-interstitial composites
  - Extended solid high energy density materials
  - Nuclear excited state spin and shape isomers

Materials and first providers

- Efficient temperature controlled storage for blood, drugs
- Measurement and sampling technologies for toxins in water and air
- Decontamination technologies for chem/bio exposure
- Simple vaccine administration systems

Materials and crime prevention

- Deterrence
  - Night-vision tools
  - Smarter, stronger access doors
  - Multifunction building technologies
  - Counterfeiting defeats
- Force protection
  - Non-lethal weapons
  - Creative restraint devices
  - Lightweight and flexible body armor

Materials and the environment

- Preventing or mitigating eco-terrorism
- Developing functional substitutes to enable flexibility and work around shortages

Conclusions

- There are always bigger priorities
  - And materials is always an enabling technology
- Research funding is increasingly complex
  - Old organizations with new mandates
  - New organizations, both private and government
- Materials are always part of other systems
  - Partnering with component designers paramount
  - No more single-property improvements
  - All materials need to be multifunctional, composite, and smart
  - Cross-disciplinary teams will be most effective - need to think outside both boxes

Organizational changes

- Department of Homeland Security (DHS)
  - Dr. Charles E. McQueary confirmed as Under Secretary for Science and Technology
  - Proactive vs reactive S&T balance unknown
  - Current capabilities being assessed
- Intelligence Technology Information Center (ITIC)
  - Increases in funding and personnel across these agencies
- Office of Management and Budget (OMB)
  - May issue guidelines on handling of sensitive security information

DoD IC members:

- Defense Intelligence Agency (DIA) - provides timely and objective military intelligence to warfighters, policymakers, and force planners.
- National Security Agency (NSA) - collects and processes foreign signals intelligence information for our Nation's leaders and warfighters, and protects critical US information security systems from compromise.
- National Reconnaissance Office (NRO) - coordinates collection and analysis of information from airplane and satellite reconnaissance by the military services and the CIA.
- National Imagery and Mapping Agency (NIMA) – provides timely, relevant, and accurate geospatial intelligence in support of national security.
- Army, Navy, Air Force, and Marine Corps Intelligence Agencies –each collects and processes intelligence relevant to their particular Service needs.

Non-DoD IC members:

- Central Intelligence Agency (CIA) - provides accurate, comprehensive, and timely foreign intelligence on national security topics to national policy and decision makers.
- State Department – deals with information affecting US foreign policy.
- Energy Department – performs analyses of foreign nuclear weapons, nuclear non-proliferation, and energy security-related intelligence issues in support of US national security policies, programs, and objectives.
- Treasury Department – collects and processes information that may affect US fiscal and monetary policy.
- Federal Bureau of Investigation – deals with counterespionage and data about international criminal cases.
- United States Coast Guard – deals with information related to US maritime borders and Homeland Security

Some related links

- The National Academies
  - www.nationalacademies.org
  - www.nap.edu
- Department of Homeland Security
  - www.dhs.gov
- February issues of JOM
  - doc.tms.org/servlet/ProductCatalog?container=JOM+2003+February
- Global Trends 2015
  - www.odci.gov/nic/pubs/2015_files/2015.htm