Department of Defense Science and Technology Program

-- A Time of Continued Change --

Mr. Al Shaffer
Principal Deputy
Defense Research and Engineering
15 April 2008

VISION: To develop technology to defeat any adversary on any battlefield

Any Battlefield includes physical, cyber, space, undersea, etc

The Evolution to New Ideas

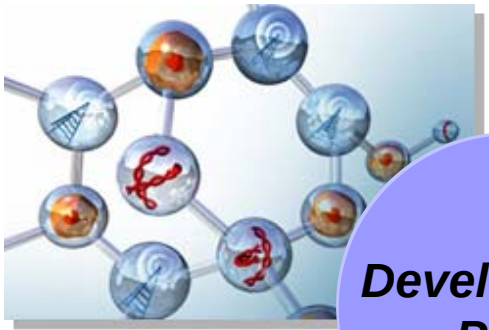
The DoD, Like the World, is moving from Physics Based to Multidisciplinary and Non-Kinetic Science

"Any sufficiently advanced technology is indistinguishable from magic."
~Arthur C. Clarke

"In times of change, learners inherit the Earth, while the learned find themselves beautifully equipped to deal with a world that no longer exists"

Eric Hoffer

A Changing World . . .



Disruptive Military Uses of Commercial Tech

Impact of Mass Collaboration

Development Pace

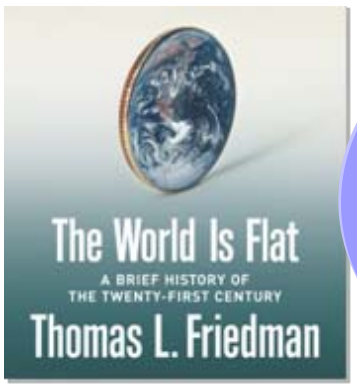
Emerging Technology

Economic Mega Trends

Expansion Of R&D Funding

The Black Swan Syndrome

The Expanding Education Base



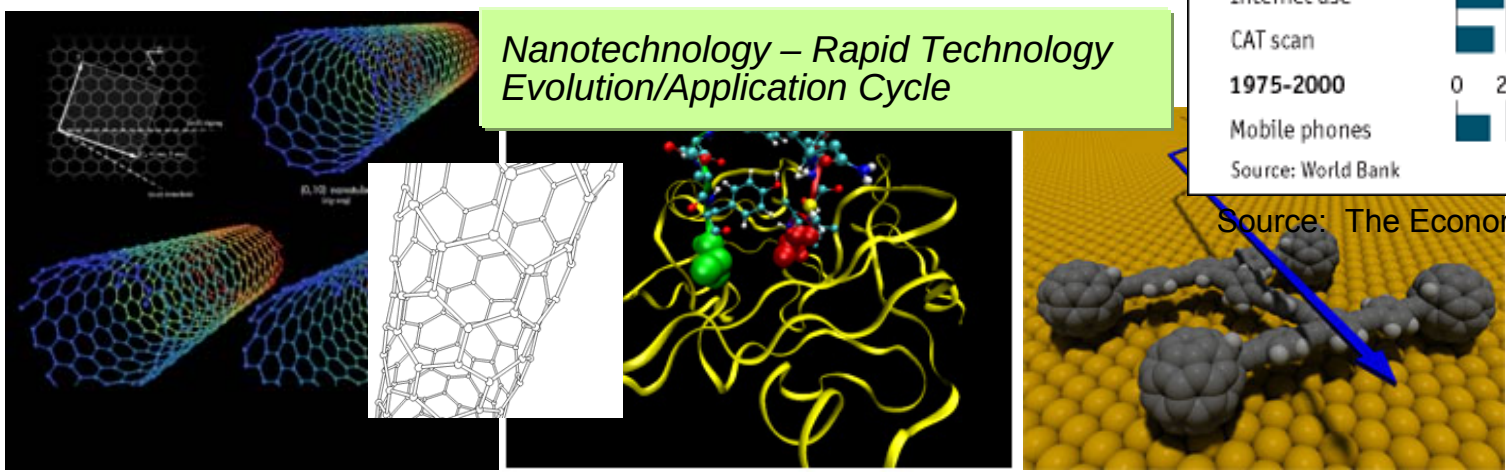
There are students in China, Australia, Austria, Bangladesh, and the USA who

collaborate

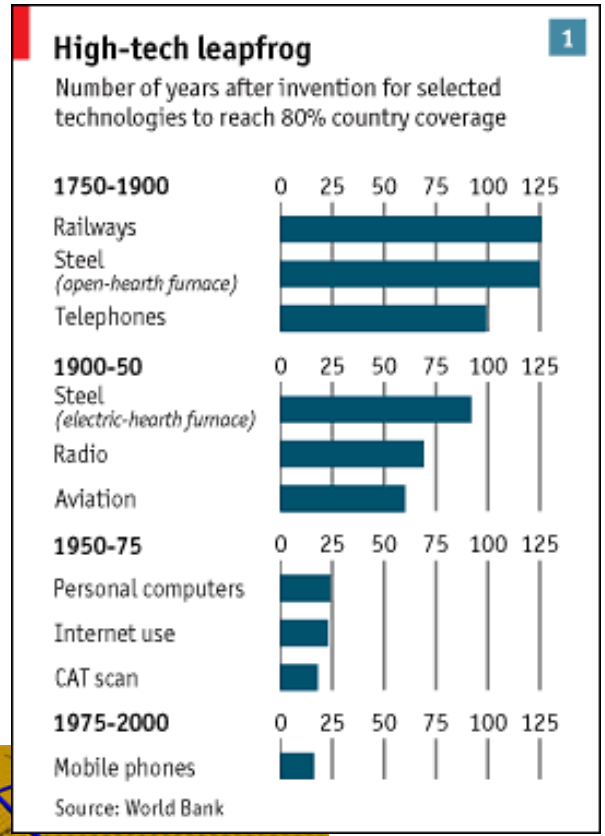
on projects everyday

Pace of Technology Continues to Increase

- **Time between modeling of semiconducting properties of germanium in 1931 and first commercial product *(transistor radio)* was 23 years**
- **Carbon nanotube**
  - **Discovered by Japan (1991)**
  - **Researchers recognized carbon nanotubes were excellent sources of field-emitted electrons (1995)**
  - **"Jumbotron lamp" - nanotube-based light source available as commercial product (2000)**



Nanotechnology – Rapid Technology Evolution/Application Cycle

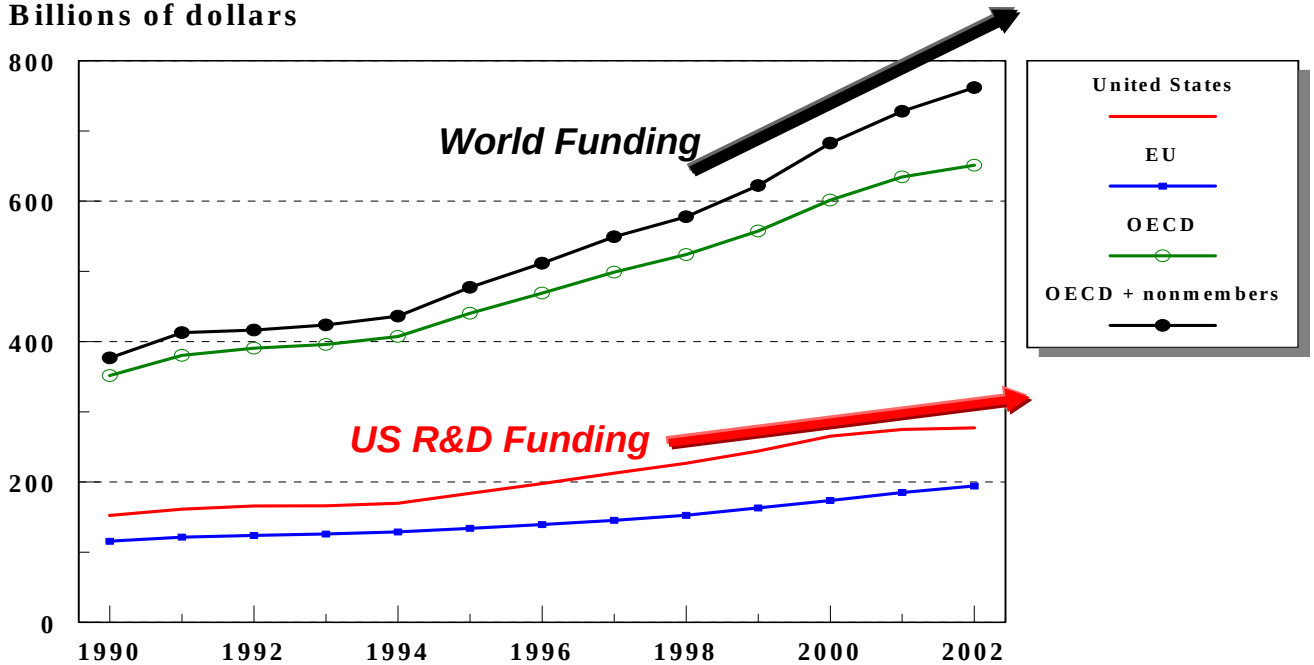


Source: The Economist, Feb. 9, 2008

International R&D trends

- **R&D expenditures are increasing robustly around the world, driven by both governments and industry.**

Figure 1. Estimated worldwide R&D expenditures: 1990-2002



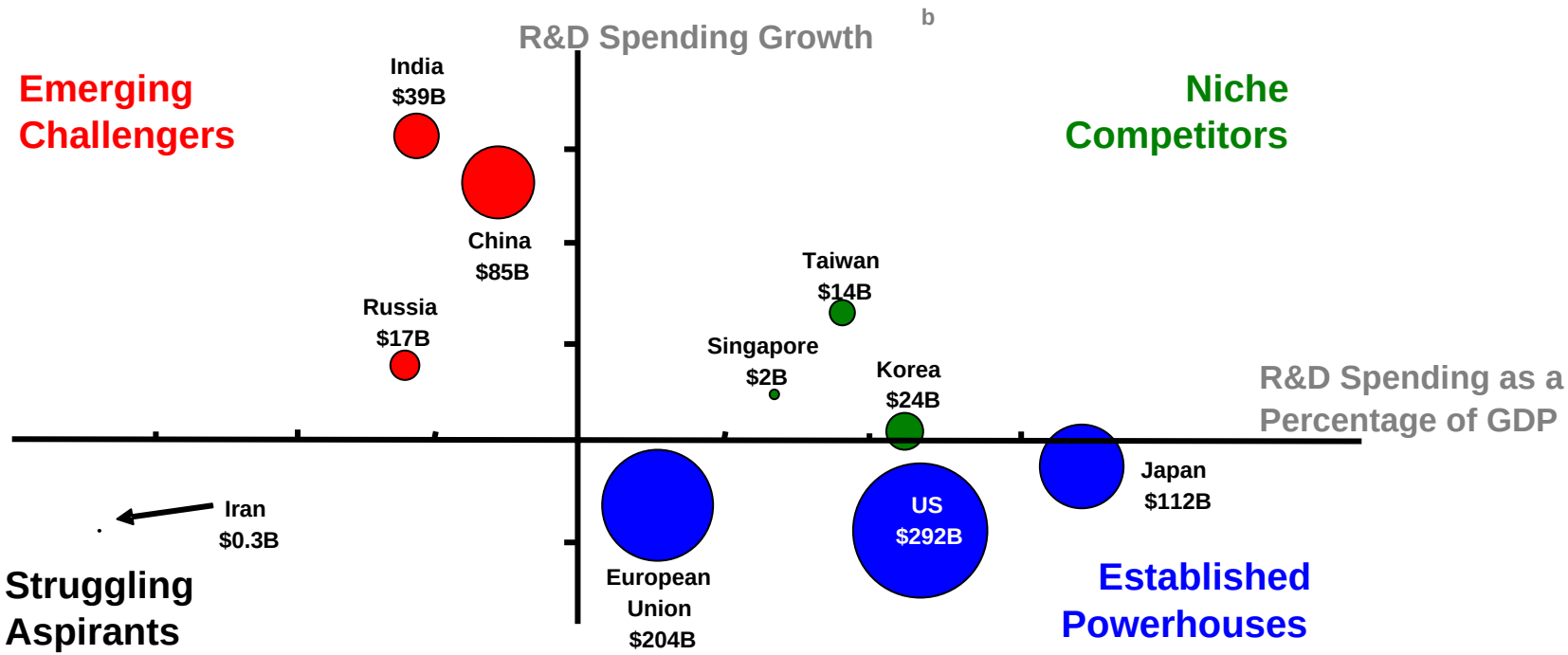
NOTE: Billions of current dollars converted with purchasing power parities.
EU data since 1998 include 10 new member countries.
SOURCE: OECD, Main Science and Technology Indicators database, November 2004

Source: National Science Foundation, S&E Indicators 2006

Global Technology (R&D) Spending and Growth

The R&D Spending Landscape - Selected Entities [a]

(Circle size reflects R&D spending levels.)

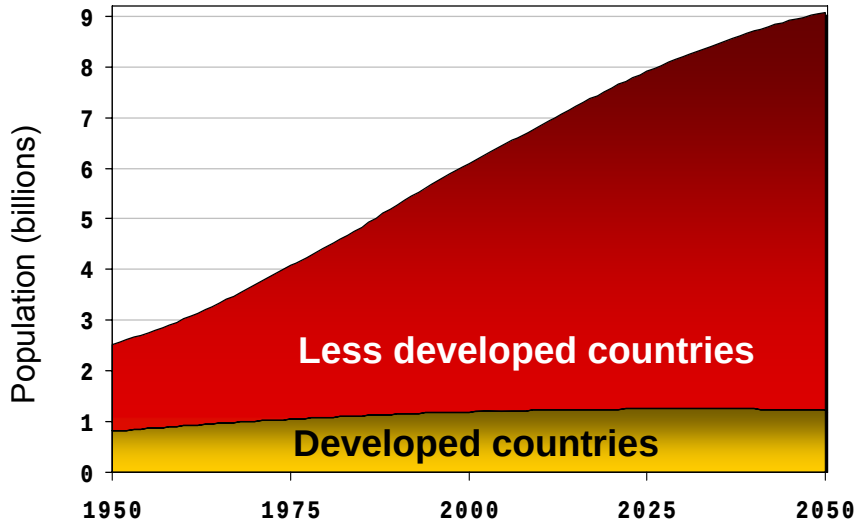


[a]R&D spending as a percentage of GDP and spending growth are defined in Figures 1 through 3. R&D spending levels are in current billions of PPP dollars.
[b]Growth rates are calculated since 2000, except for Russia, which was calculated since 1992 due to high uncertainty in the regression since 2000.
Sources: OECD, Main Science and Technology Indicators Volume 2005; UNESCO, Science Report 2005; Indian Ministry of Science and Technology, S&T Annual Report 2004-2005; H. Arfaei, "Status of Scientific Research -- Iran 2005", April 2005; CIA World Fact Books, 1981-1990, 1997- 2004; and World Bank, Development Indicators database, 1981-1990, 1997-2004.

Demographic Trends

- Demographic trends are the most predictable of the trend sets
- The major trends with significant defense implications:
  - North-South divide in age structure
    - Demographic "bonus" India, Latin America
    - Youth bulges in fragile states and migrant populations
    - Aging and low birth rates in key allies & China
  - International and internal migration
    - Push away from trouble
    - Pull to economic opportunity
    - Migrating political interests
  - Youth, conflict, and ideology
  - Urbanization

Massive Population Growth

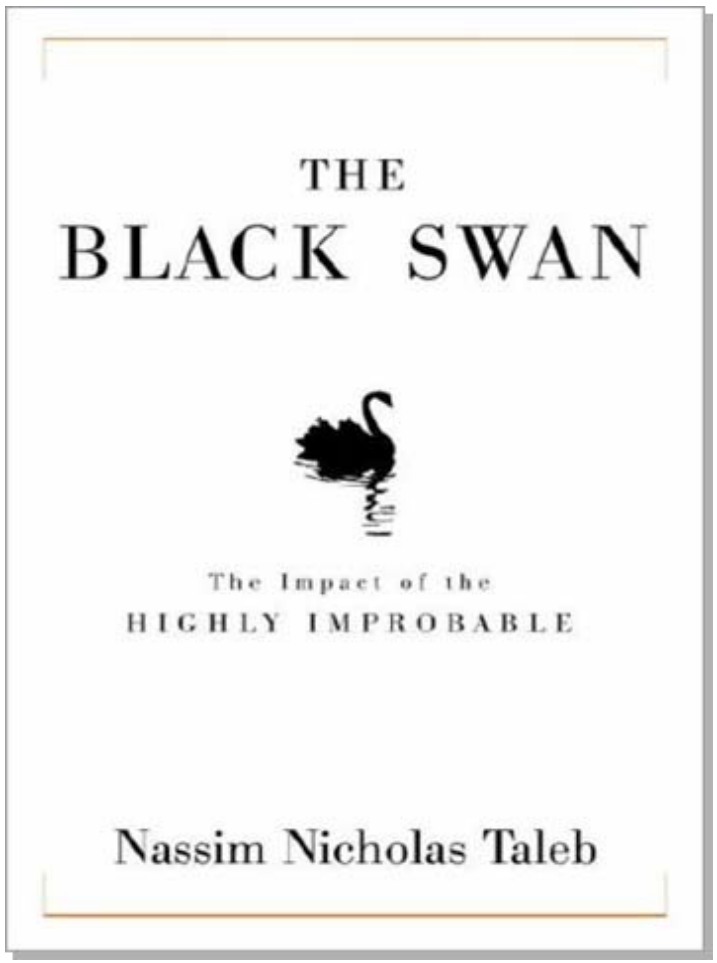


(Source: UN, World Population Prospects, The 2006 Edition, 2007)

Demographic change will increase stress on fragile states, create risks around access to resources, and generate a range of governance, societal, cultural, & health issues as states adjust to population transformations within and between states

The “Black Swan” Syndrome

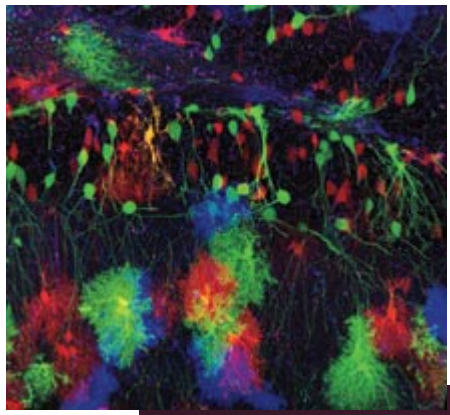
Cognitive biases create false expectations of predictability. Acknowledging uncertainty may allow us to adapt better to unforeseen events.

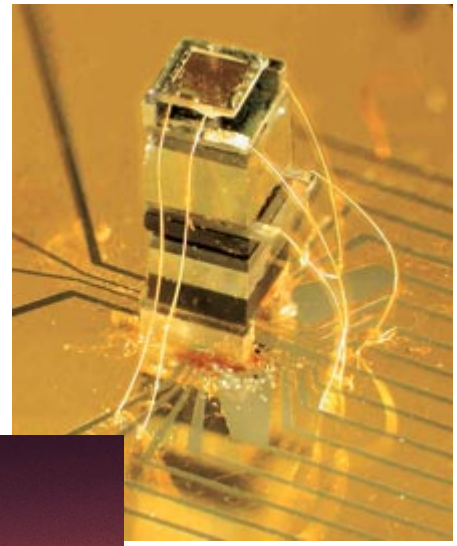


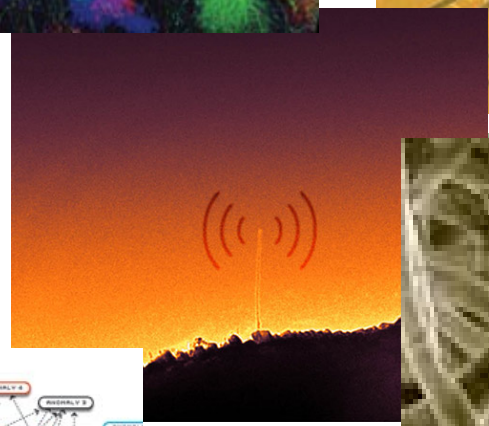
- “Black Swans”: ***large-impact, impossible to predict, and rare event beyond the realm of normal expectations***
  - 9/11, Google, internet bubble
- “Outside context problem”: ***Problem outside a given groups experience, with an immediate, ubiquitous and lasting impact upon it***
  - Perry’s Black Ships arriving in Japan
- “Accelerating change”: ***increase in rate of technological/ cultural/social progress in history (contrast to linear view)***
  - Accumulation of knowledge, access to knowledge and lowering of transactional barriers to knowledge

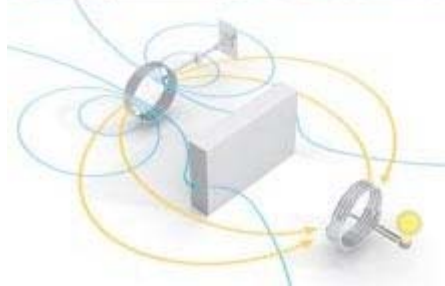
March/April 2008 MIT Innovations List of 10 Emerging Technologies

- *Cellulolitic Enzymes*
- *Atomic Magnetometers*
- *Surprise Modeling*
- *Connectomics*
- *Probabilistic CMOS*
- *Reality Mining*
- *Offline Web Applications*
- *Graphene Transistors*
- *Nanoradio*
- *Wireless Power*

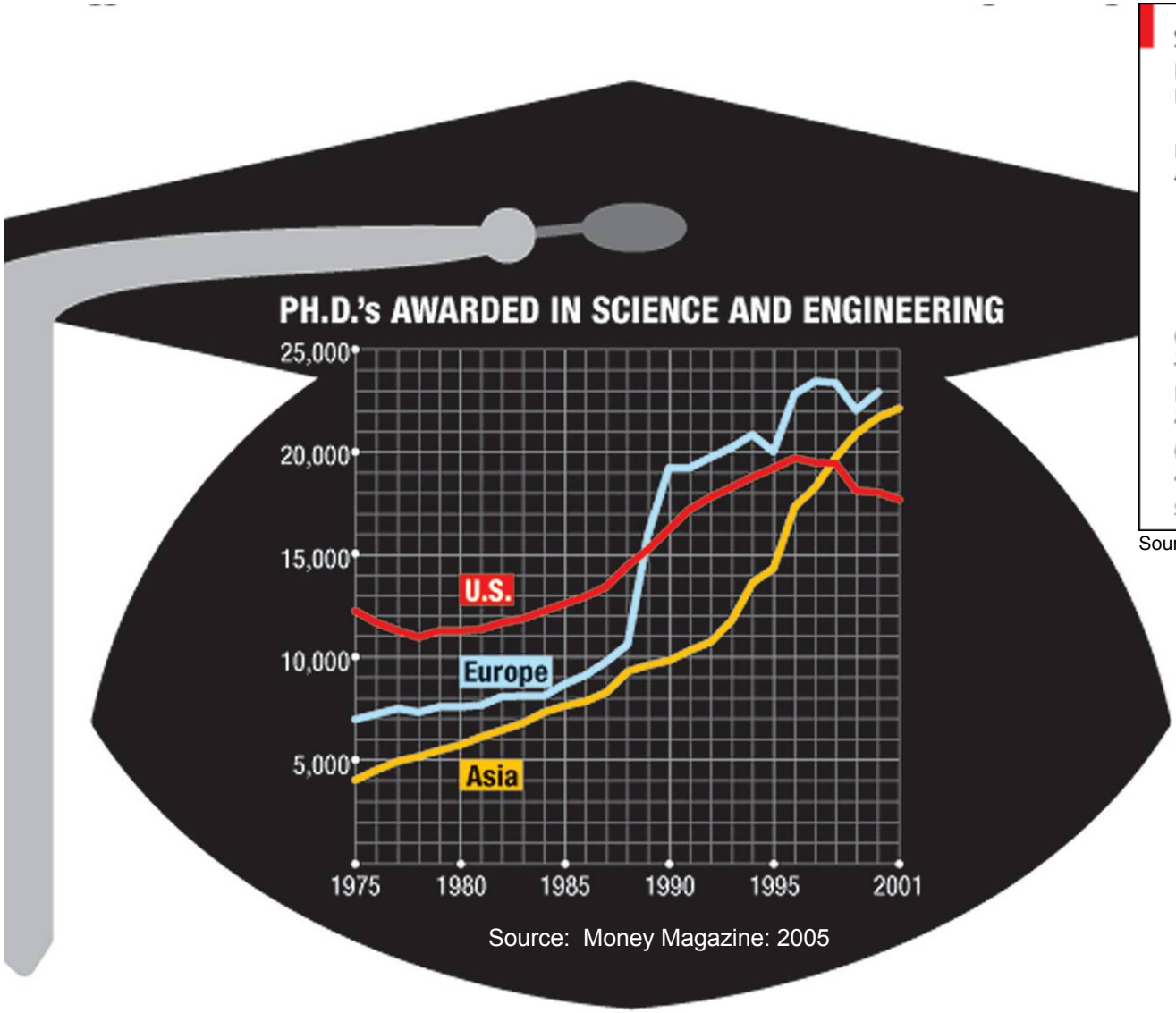




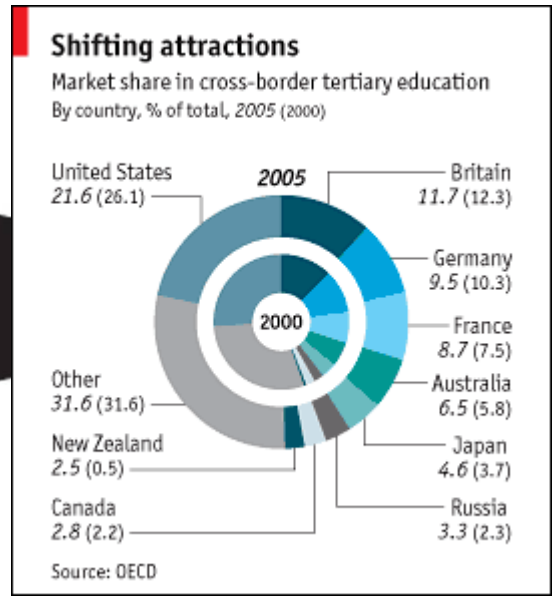




Comparison of Scientists & Engineers (S&Es)



Source: Money Magazine: 2005



Source: The Economist, Nov. 15, 2007

http://www.economist.com/research/articlesBySubject/displaystory.cfm?subjectid=2133650&story_id=10143247

Growth of Educated Asian Population

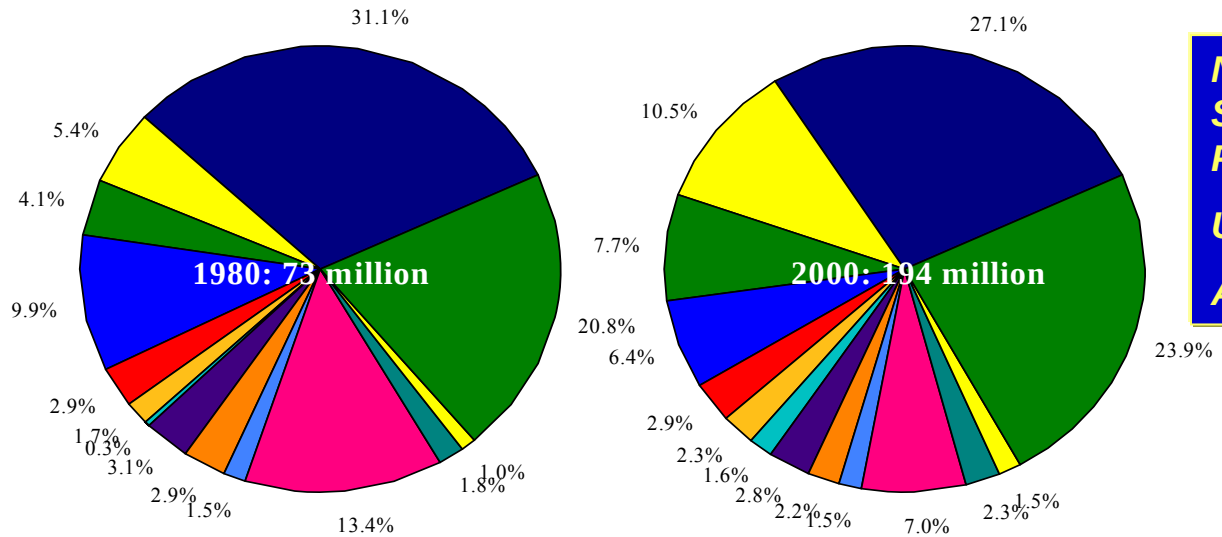
- **International S&E labor force data can only be approximated.**

Figure 20. Population 15 years and older with tertiary education, by country/region: 1980, 2000

Number in S&E Labor Force, 1980:

US 22.8M

Asia: 17.7M



Number in S&E Labor Force, 2000:

US 52.6M

Asia: 60.9M

SOURCE: Adapted from R.J. Barrow and and J. Lee, Center for International Development: International Data on Educational Attainment, 2000

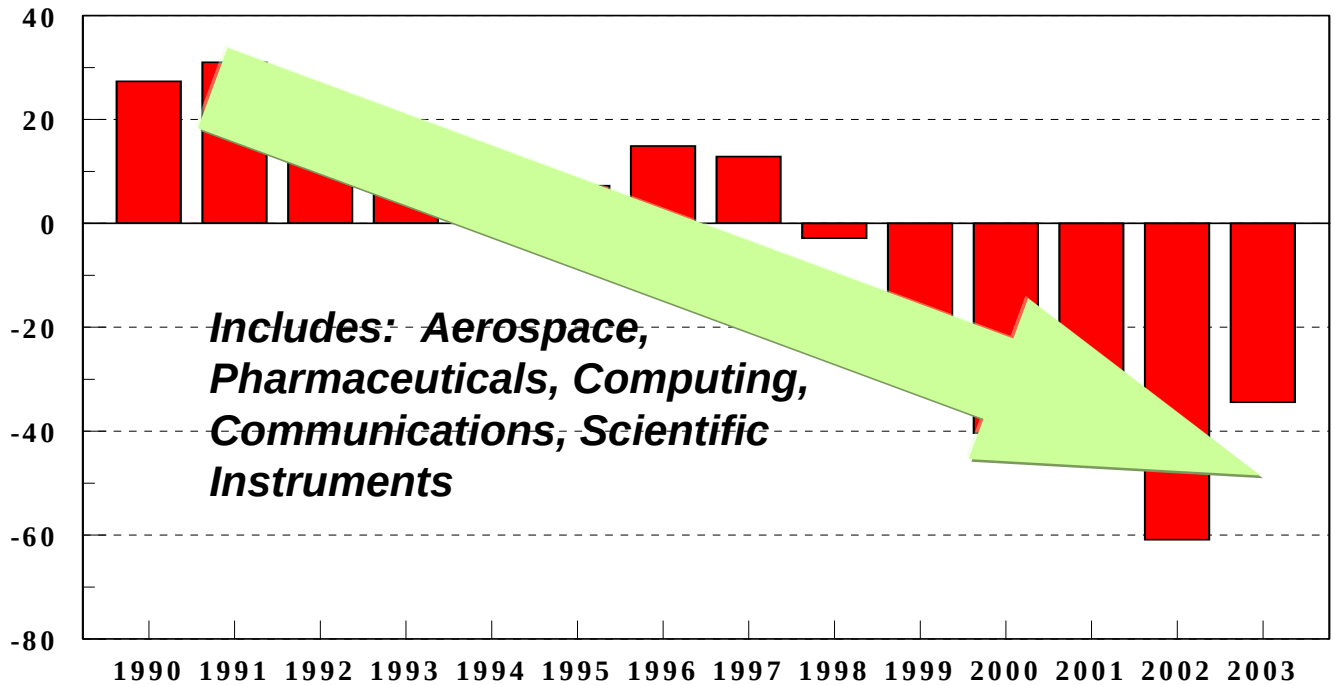
Source: National Science Foundation, S&E Indicators 2006

U.S. trade balance – high tech industries

- **The trade balance of U.S. high technology industries has turned negative**

Figure 12. U.S. trade balance for five high technology industries: 1990-2003

Billions of dollars



NOTE: Includes aerospace; pharmaceuticals; office and computing equipment; communication equipment; and scientific instruments.

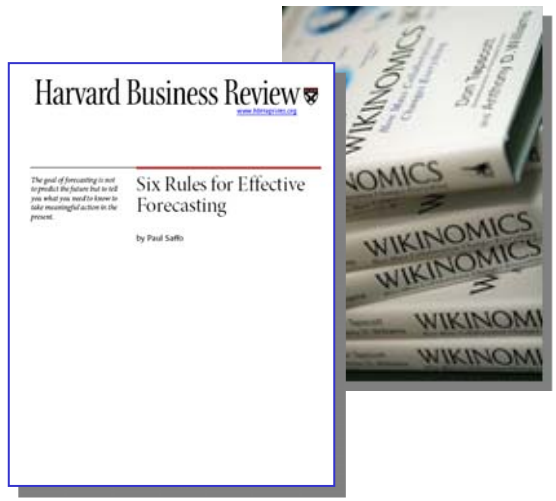
SOURCE: Global Insight and S&E Indicators 2006

Source: National Science Foundation, S&E Indicators 2006

Forecasting Future Disruptive Technology—Mass Collaboaration

- DoD & National Academies
- Teaming to produce a recurring technology forecast that is a:
  - Multidimensional Description of the technology
    - Estimation/description of impact
    - Temporal profile of development
  - Based on a wide group of experts
    - Develop a New web collaboration environment
    - Industry, academia, venture capitalists, government experts, etc.
    - Use collaboration environment to access a global community
  - Examines both traditional and non-traditional technology trends

Looking more than 15 years ahead . . .



Using mass collaboration as the tool for "*Effective Forecasting*"

Disruptive Technology

The Non-Textbook Definition

- **Rapid evolution from old, stable technology to new, dominating technology**
- **A technology surprise that gives a competitor an advantage**
  - **Business - Technology that overturns market**
  - **Military - Technology that causes a fundamental change in force structure, basing, and capability balance**
- **Disruptive Technologies can be intended or unintended - but both represent change**
- **Disruptive Technologies may arise from systems or enabling technology**

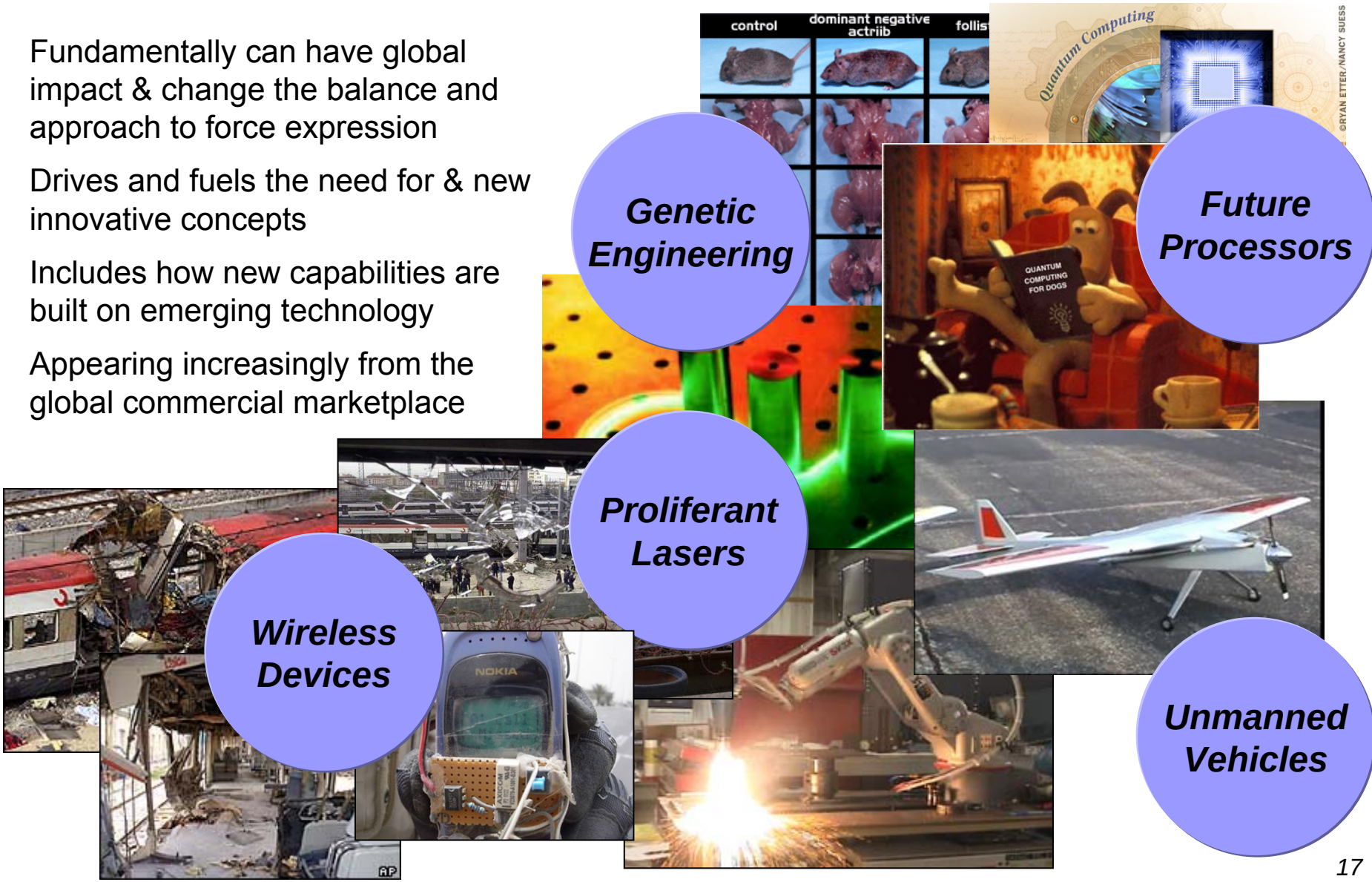
Desert Storm

- The advent of information-based warfare feeding the emergence of irregular warfare

- US dominance over Soviet-era systems “shocked” potential adversaries and combined to give US conventional superiority
  - Precision Weapons
  - Night Vision
  - Low Observability
  - Networked Systems

R&D Expansion & "Disruption"
--Applications of Commercial Technologies--

- Fundamentally can have global impact & change the balance and approach to force expression
- Drives and fuels the need for & new innovative concepts
- Includes how new capabilities are built on emerging technology
- Appearing increasingly from the global commercial marketplace



An information age Pearl Harbor?

NO….but this guy is far cry from Imperial Japan

George Hotz, 17, of Glen Rock, New Jersey holding the iPhone® that he separated from the AT&T network and used on the T-Mobile Network. Career goal: hack the human brain

- Apple and AT&T released the iPhone on 29 June
- An exclusive agreement guaranteed the iPhone could only be used on AT&T's mobile network
- Hotz spent approximately 500 hours working on his "summer project"
- The hack was announced on 24 August.

- AT&T - market cap: $245B
  - annual revenue: $90B
- Apple - market cap: $117B
  - annual revenue: $23B
- Hotz - PRICELESS

This is the new asymmetry—victory goes to the agile and innovative

Trends

- **Increasing**
  - **International Science and Technology Relative to the US**
  - **Industrial Globalization of R&D**
  - **Pace of Technology Development**
  - **US Trade Balance in High-Tech Goods**
  - **Potential for "*Hybrid*" Disruption**
  - **Mass Collaboration "*Flattening*" the world**
- **Decreasing**
  - **US Production of Global Scientists and Engineers relative to World**

US High Technology Advantage not Assured

Competition Increasing

Therefore, Have to Work on "High Payoff" Areas

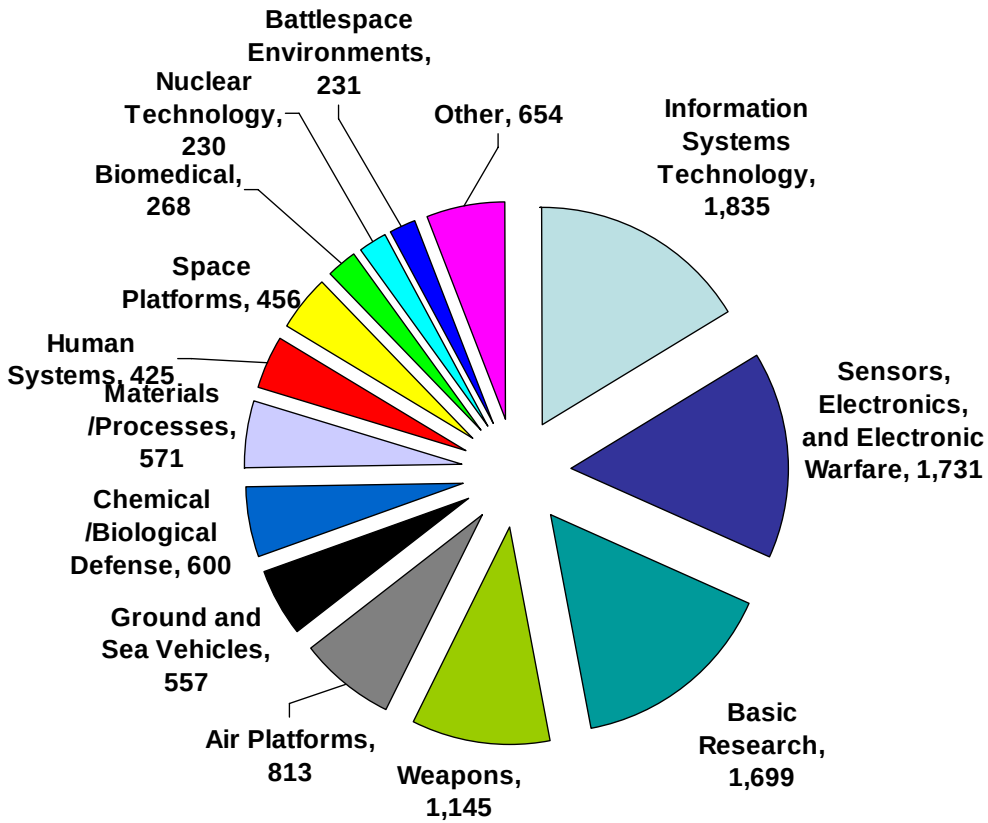
Where are we going?

S&T Strategy and Plans

Defense Science and Technology Strategy and Planning

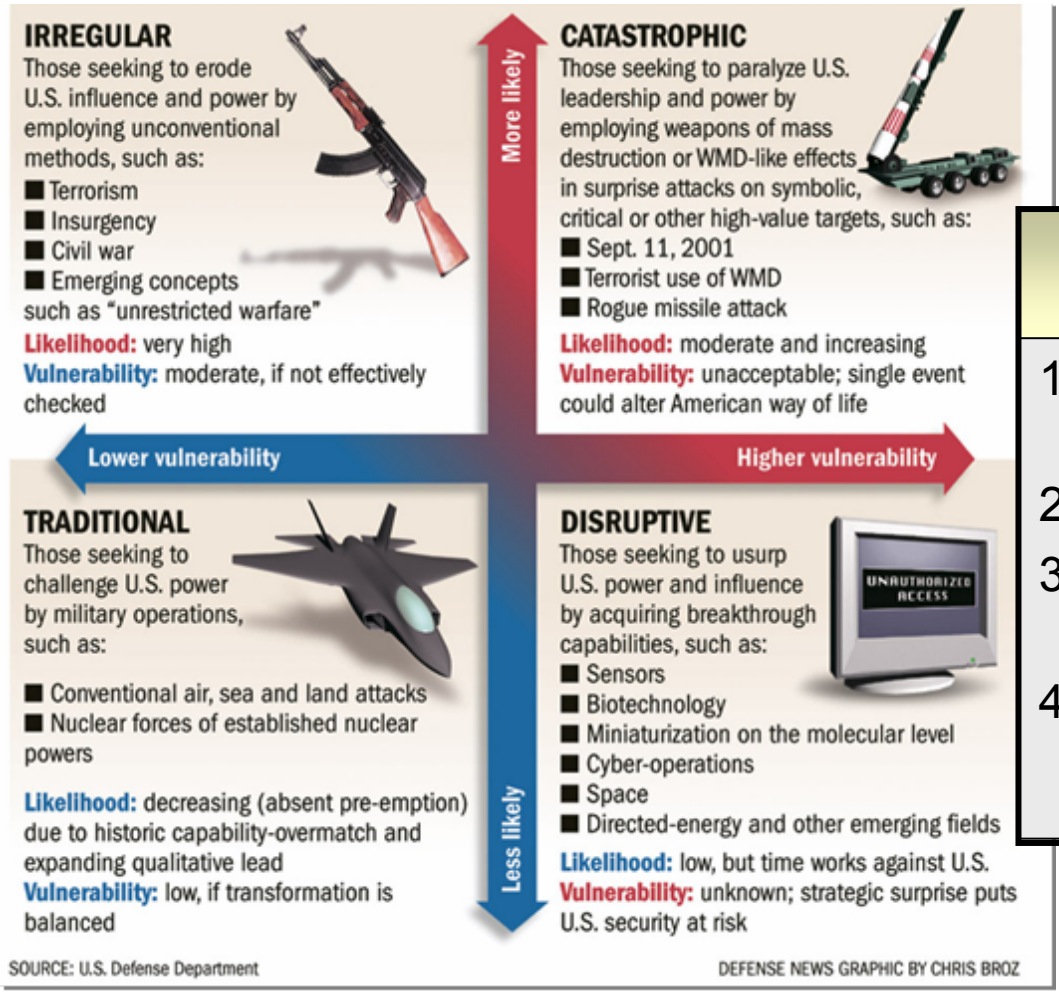
Where is the DoD S&T money going?

- **Funding**
  - Current year S&T dollars: $10.77B FY08 to $11.48B FY09
  - Percent of DoD funding: 2.24% FY08 to 2.22% FY09
  - Over 50% of total investment in 4 functional areas:
    - Information Systems (1.8B)
    - Sensors, Electronics / EW (1.7B)
    - Basic Research (1.7B)
    - Weapons (1.1B)



DoD S&T program is focused on "sensing and shooting" But is changing……

2006 QDR Challenge Construct



Four Hard Problems

1. Build partnerships to defeat terrorist extremism
2. Defend the homeland in-depth
3. Prevent acquisition or use of WMD by hostile actors.
4. Shape choices of countries at strategic crossroads

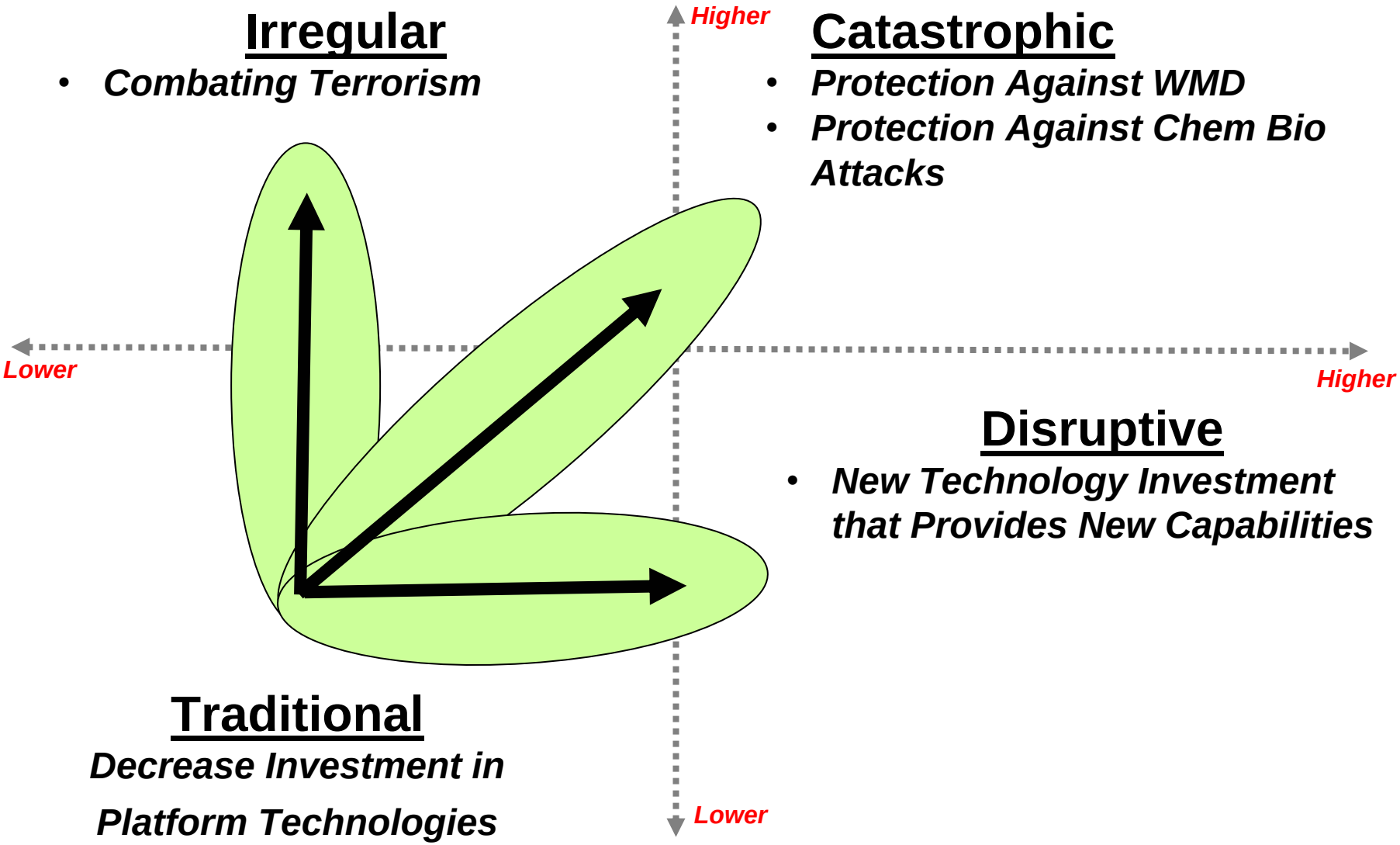
National Defense Strategy Drives Investment Strategy

Irregular

- *Combating Terrorism*

Catastrophic

- *Protection Against WMD*
- *Protection Against Chem Bio Attacks*



Disruptive

- *New Technology Investment that Provides New Capabilities*

Traditional

Decrease Investment in Platform Technologies

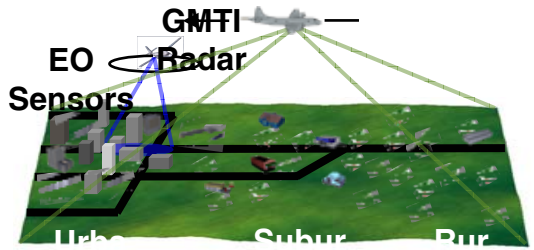
Science and Technology Enabling Technology Priorities

- **Technology focus areas:**
  - **Biometrics and Biological exploitation**
  - **Information technology and applications**
  - **Persistent Surveillance Technology**
  - **Networks and Communication**
  - **Human, Social, Cultural, and Behavioral Modeling**
  - **Language**
  - **Cognitive Enhancement**
  - **Directed Energy**
  - **Autonomous systems**
  - **Hyperspectral sensors**
  - **Nanotechnology**
  - **Advanced Materials**
  - **Energy and Power**
  - **Affordability**
  - **Combating Weapons of Mass Destruction Technologies**
  - **Energetic Materials**

In Blue—Areas with Substantial Increases in FY08/09 President's Budget Request

Increased S&T Requests Addresses Capability Gaps

- Special ("non-kinetic"/enabling) technologies:
  - Clandestine Tagging, Tracking and Locating
  - Biometrics
  - Human, Cultural, Social Behavior Modeling
  - Networks
  - Persistent Surveillance



- Technologies to decrease energy consumption/increase alternatives
- Combat and tactical armor for protection against a range of threats
- Accelerating transition to fielded systems

Investment shifted away from platform-specific technologies

Increased S&T Requests Addresses Capability Gaps

- New technology/emphasis areas
  - $270M increase to Basic Research
    - SecDef initiative to increase peer-reviewed basic research
      - To develop innovative solutions
      - Enhance the science and engineering personnel base
    - Increase will support targeted focus areas for
      - Early to mid-career scientists and engineers with a team of students and post docs
      - Single Investigator awards with larger grants
    - Emphasis will be on emerging technology areas, e.g.,
      - Cyber protection and information assurance
      - Biosensors and biometrics
      - Human sciences (cultural, cognitive, behavioral, neural)
      - Software sciences and materials
      - Immersive sciences for training and mission rehearsal
      - Power and energy management
    - Anticipate about 500 focused research efforts

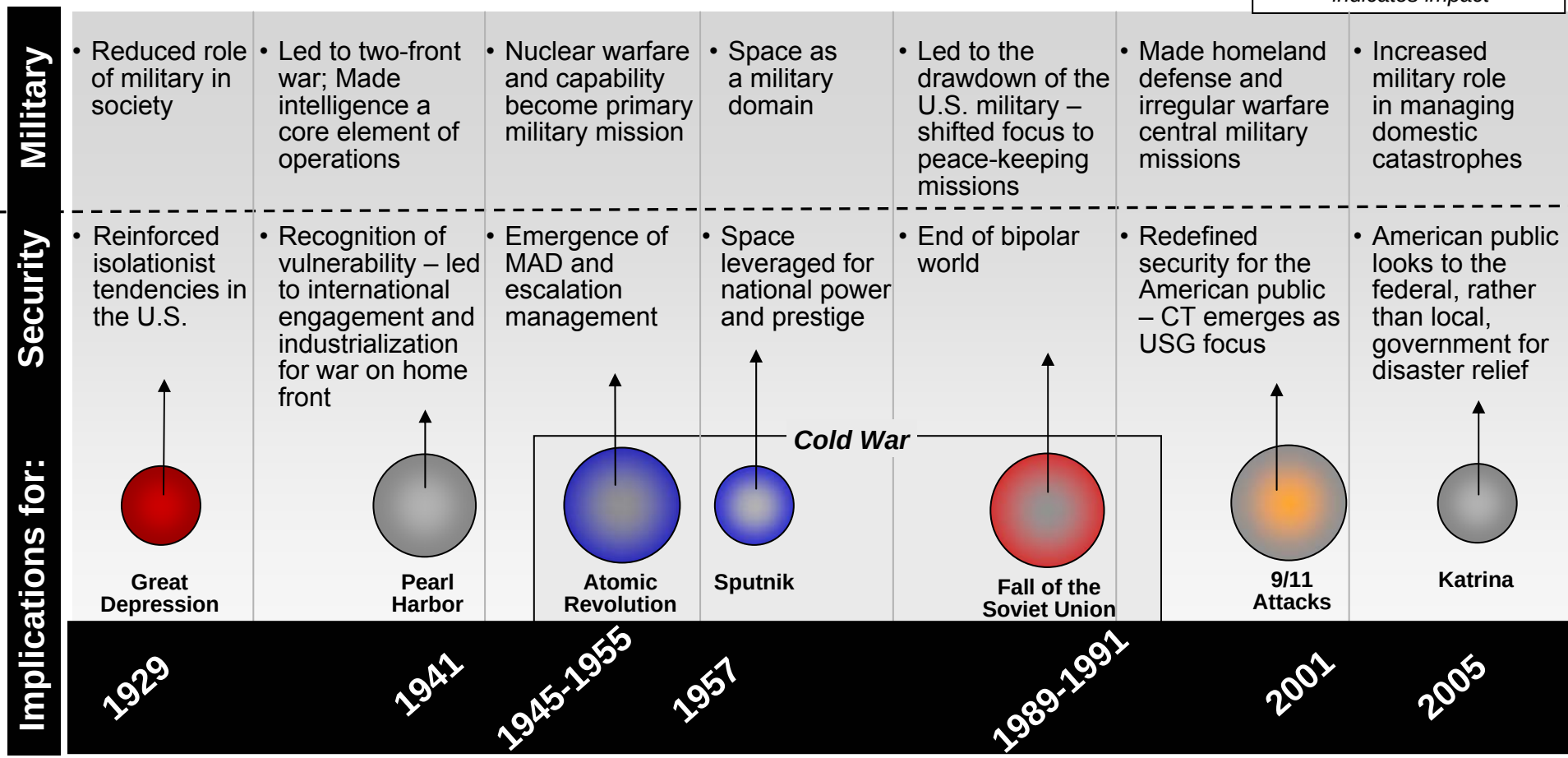
Increased S&T Requests Addresses Capability Gaps

- New technology/emphasis areas *(Cont'd)*
  - Increased protection for dismounted troops and ground forces
  - Research in plasma and meta-materials to address emerging threats
  - Cyber protection
  - Hypersonics/Prompt Global Strike (Blackswift) – New technology prototype **

Shocks from the Past Century

Categories of trends
- Conflict
- Demographics
- Economy
- Environment
- Governance
- Science & Technology
- *Note: Size of circle indicates impact*

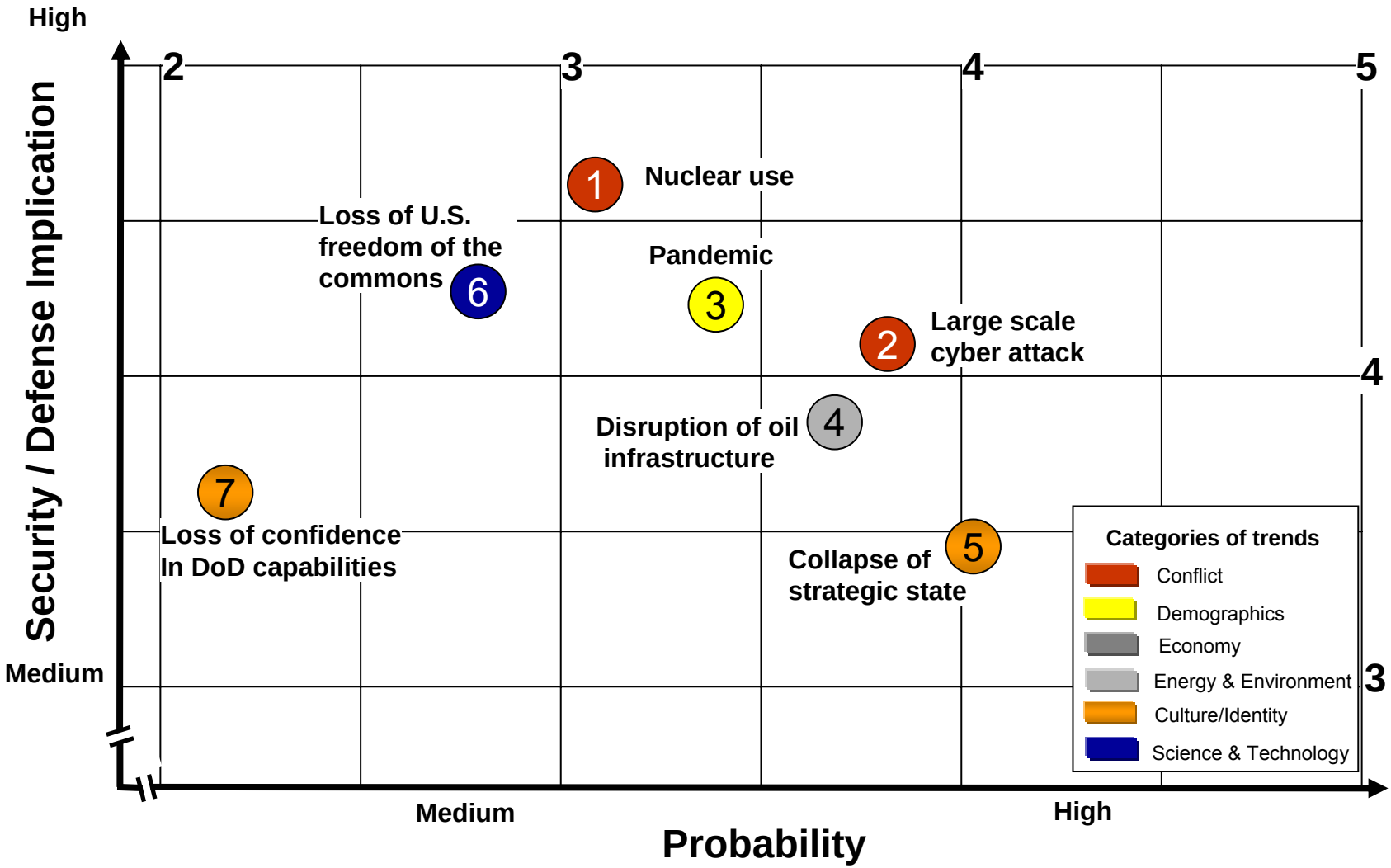
- **Strategic shocks can change how we think about security and the role of the military, e.g.:**



In retrospect, these shocks were the product of long-term trends

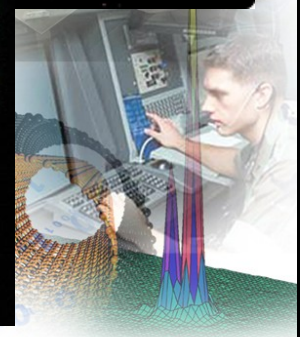
Analysis of Potential Shocks (2 of 2)

- Relative impact and likelihood out to 15 years



VISION: To develop technology to defeat any adversary on any battlefield

Any Battlefield includes physical, cyber, space, undersea, etc



Transformation

QUESTIONS?

Young Memo

- **Technology focus areas:**
  - **Active and Conventional Armor Technology**
  - **Defeat Speed of Light Systems**
  - **Immersive Training**
  - **Cyber Protection**
  - **Handling Large Data Sets**
  - **Human, Social, Cultural, and Behavioral Modeling**
  - **Cognitive Enhancement**
  - **Autonomous systems**
  - **Hyperspectral sensors**
  - **Nanotechnology**
  - **Advanced Materials**
  - **Energy and Power**
  - **Biometrics**
  - **Network Technology**
  - **Combating Weapons of Mass Destruction Technologies**

In Blue—Areas with Substantial Increases in FY08/09 President's Budget Request

2006 RAND Study*: Top 16 Technology Applications

Need to understand the second-order effects of emergent technologies on the DoD

- ⇒ Cheap solar energy
- ⇒ Rural wireless communications
- ✓ Communication devices for ubiquitous information access anywhere, anytime
- • Genetically modified (GM) crops
- ⇒ Rapid bioassays
- ⇒ Filters and catalysts for water purification and decontamination
- ⇒ Targeted drug delivery
- • Green manufacturing
- ✓ Ubiquitous RFID tagging of commercial products and individuals
- ⇒ Hybrid vehicles
- ✓ Pervasive sensors
- ⇒ Tissue engineering
- ⇒ Improved diagnostic and surgical methods
- ⇒ Wearable computers
- ✓ Quantum cryptography
- • Cheap autonomous housing

✓ *Direct Military Application*

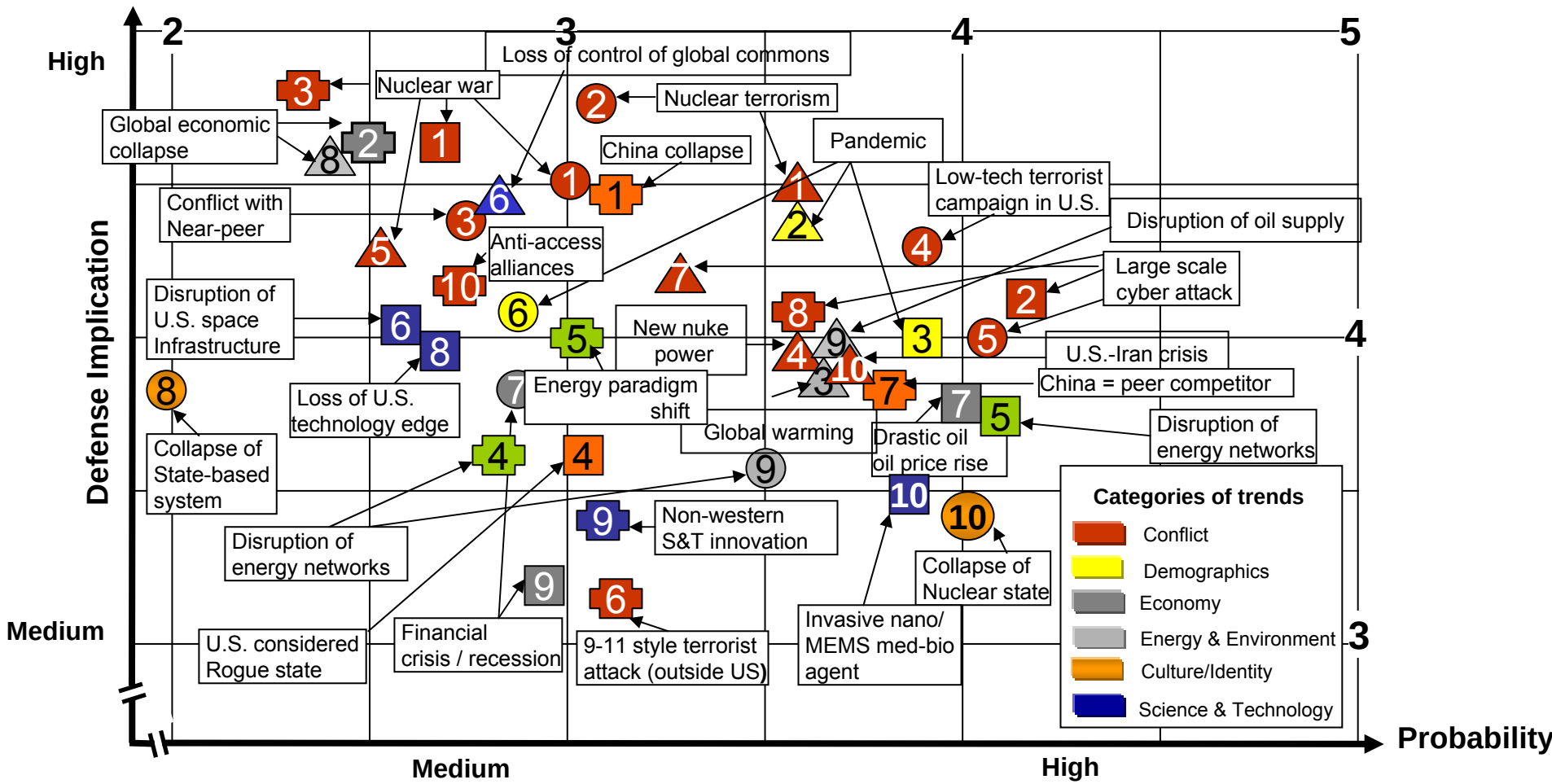
⇒ *Indirect Military Application*

• *No Military Application*

** The Global Technology Revolution 2020, In-Depth Analyses*

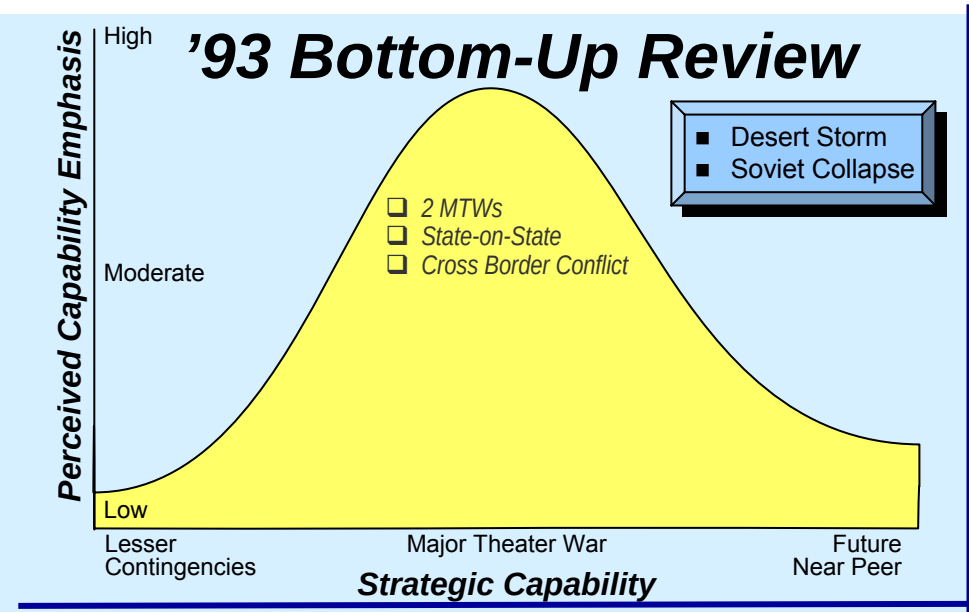
Analysis of Potential Shocks (1 of 2)

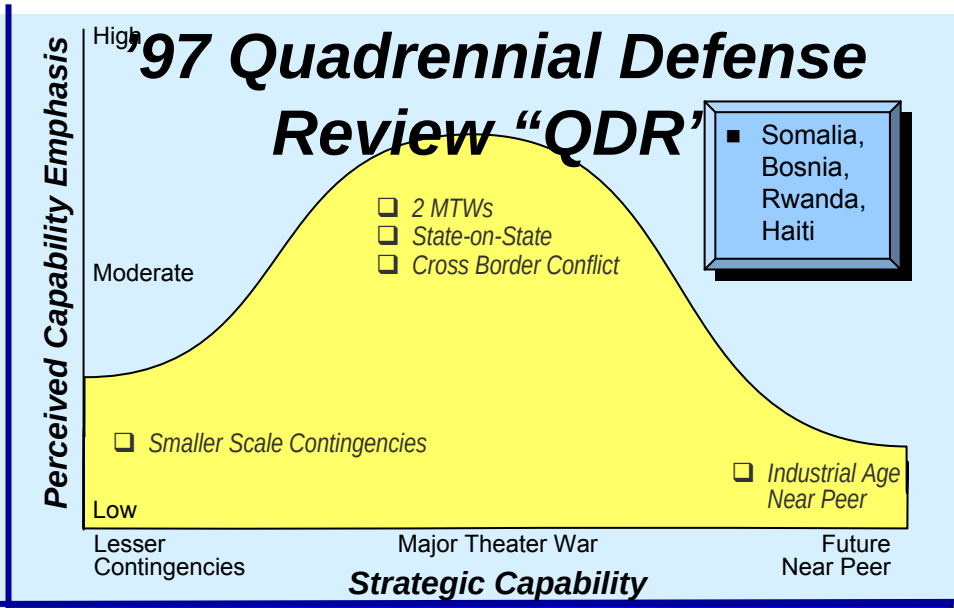
- **Relative impact and likelihood out to 15 years**

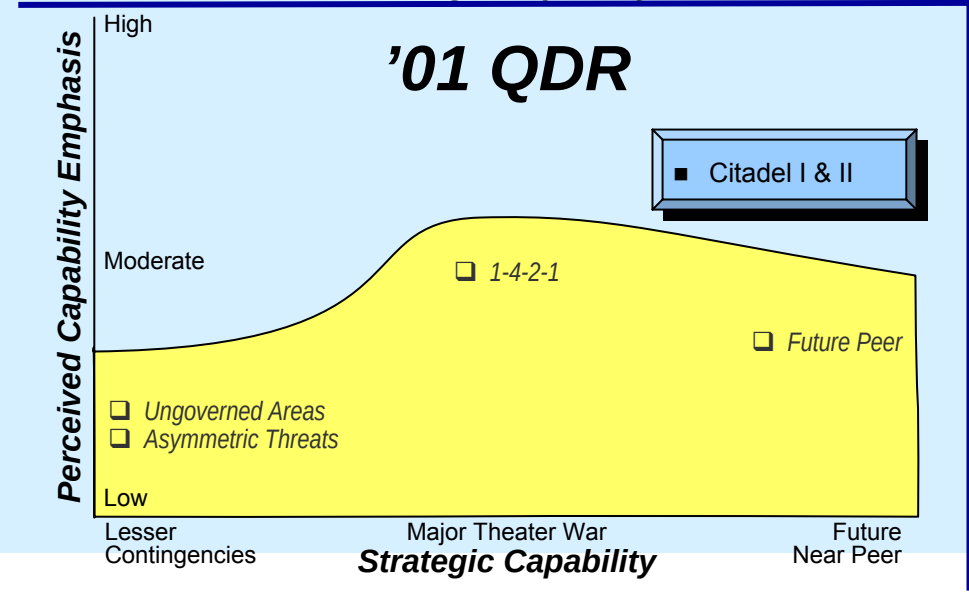


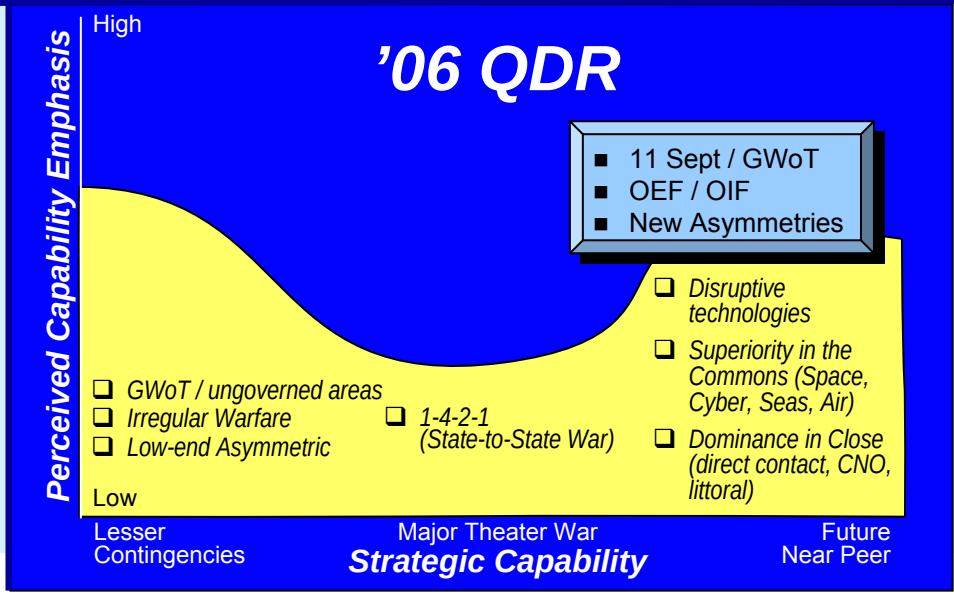
Source: Compare and contrast three symposiums: 08 June, 27 August, 25-26 September 2007 and 18-19 December 2007 Johns-Hopkins University APL Warfare Analysis Laboratory, Laurel MD and Booz Allen Hamilton Inc, Herndon VA

Decade of Strategic Evolution









Building the Science and Engineering Base

- We need to continually develop, mature and field technology to stay ahead of our adversaries
- President Bush acknowledged the importance of science and engineering development in his January 2008 State of the Union address

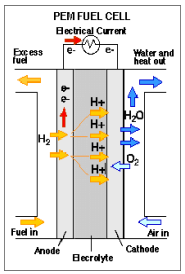
"To keep America competitive into the future, we must trust in the skill of our scientists and engineers and empower them to pursue the breakthroughs of tomorrow… I ask Congress to double federal support for critical basic research in the physical sciences and ensure America remains the most dynamic nation on Earth.."

President George W. Bush, State of the Union address, January 28, 2008

"As changes in this century's threat environment create strategic challenges – irregular warfare, weapons of mass destruction, disruptive technologies – this request places greater emphasis on basic research, which in recent years has not kept pace with other parts of the budget."

Secretary of Defense Posture Statement on the FY09 Budget, February 2008

Energy Security Challenge



Supply

- **Conventional fossil fuels**
- **Synthetic fossil fuels** (e.g. coal, shale oil and tar sands derived fuels)
- **Alternative fuels** (e.g. biodiesel, alchohols, hydrogen, etc.)
- **Renewables** (e.g. solar, geothermal, wind)
- **Novel supply** (e.g. fuel cells)
- **Exotics** (e.g. isomers)

$$CH_4 + \tfrac{1}{2}O_2 \rightarrow 2H_2 + CO$$
$$(2n+1)H_2 + nCO \rightarrow C_nH_{2n+2} + nH_2O$$

Demand

- **Conservation Initiatives**
- **Fixed base**
- **Tactical base**
- **Platforms**
- **Efficiency**
- **Life-Cycle Cost**

Assured Distribution

- **Direct oil / fossil fuel costs**
- **Policy, processes and risk assessment**
- **Refining Capacity**
- **Doctrine**

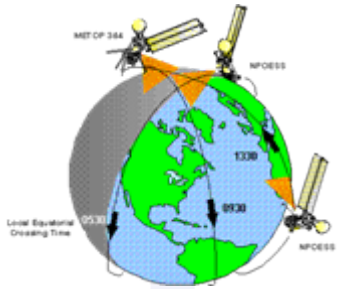
Convergence for Energy Security

DoD S&T is a Partnership

Link to the Warfighter

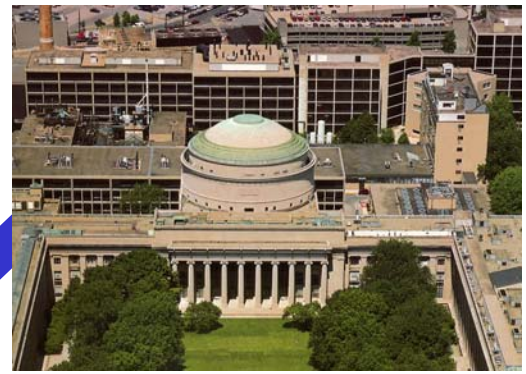
Service Labs

Expanded Resource Base



Interagency

New Ideas, Knowledge

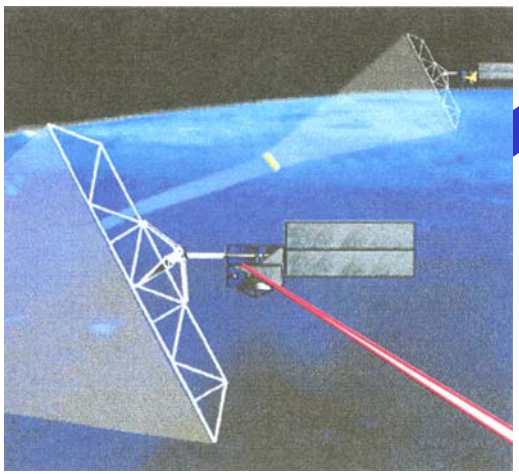


Universities

Industries

Maximum National Security Payoff

DARPA



High Risk, High Payoff

International

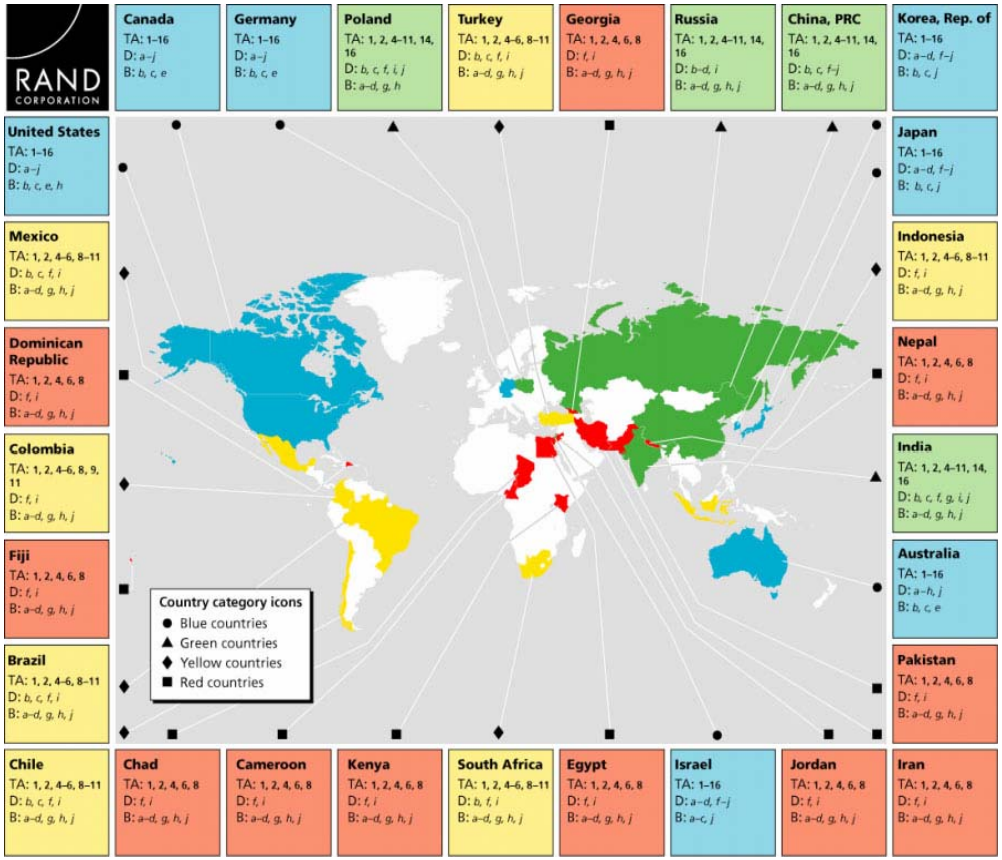
Coalition Capability

Innovation, Transition

Selected Countries Capacity to *Acquire* the Top 16 Technology Applications*

Scientifically advanced

Scientifically proficient



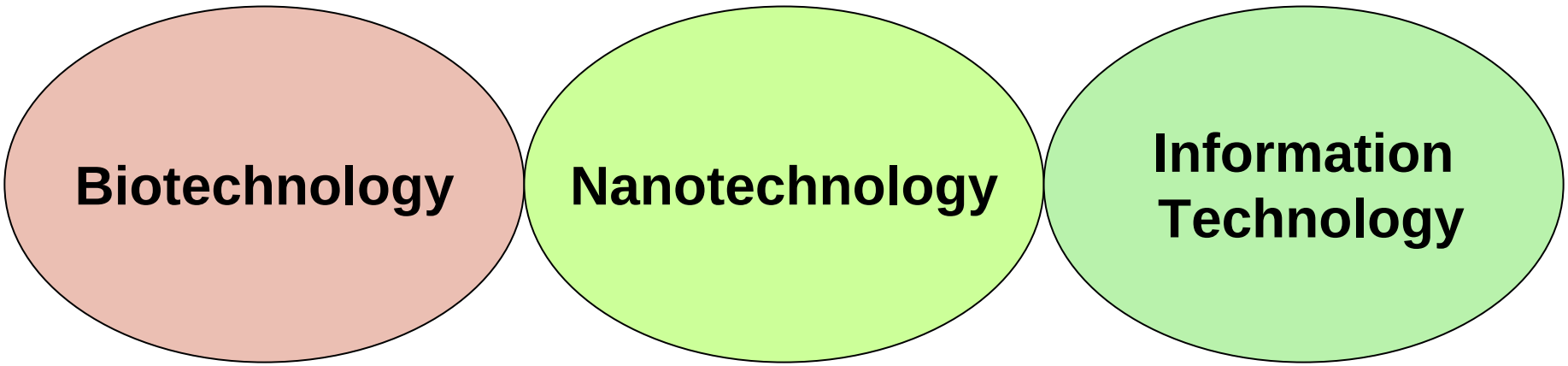
Scientifically developing

Scientifically lagging

*** The Global Technology Revolution 2020, In-Depth Analyses***

- ***Held at Irvine Ca, Nov 2006***

- ***The Most Probable Future Technology Shocks areas are:***



Potential Military Applications:

- **High Energy Fuels**
- **Bio-based Computers**
- **Advanced Materials**
- **Energy Storage / Distribution**
- **Assisted Decision Making**
- **Aided Target Recognition**

Science and Technology and the Joint Warfighter

MG William J. Troy

Vice Director
Force Structure, Resources, and Assessment
Joint Staff, J8

Joint Staff Roles in S&T

- The "Voice of the Warfighter"
  - Consolidate needs of the COCOMs (via Integrated Priority Lists – IPLs) into JROC validated Capability Gaps
  - JUONs
  - JCTD validation

BOTTOM LINE:

Ensure the Joint Warfighter has the required capabilities to execute the assigned mission in a resource constrained environment…

JCIDS Update

- Senior Warfighters' Forums (SWarFs)
- Focus on Cross-cutting Issues
- JCA Rebaseline
  - Nine Tier 1 JCAs
    - Approved by DAWG to Tier 3
  - Two new FCBs:
    - Building Partnerships
    - Corporate Management
- Gap Prioritization
  - New Integrated Priority Lists (IPLs) from COCOMs recently submitted, gap analysis/formulation/ prioritization in progress
- FY08 NDAA Provisions

Warfighter-Influenced Direction for DoD S&T…

- What has 5 years of war told us to help shape the direction of DoD S&T?
  - ISR
    - Readily available and tailorable coverage
  - Robotics
    - Same/improved capabilities, keeping Soldiers and Marines out of harm's way
  - Force Protection
    - Armor Protection vs. Armor Defeat – where does it end?
  - Managing violence in a dense battlespace
    - Interoperability, C2, Precision Fire

Interoperability and Interdependence on Demand in a Fluid Situation

- Ground Forces
  - Army Tanks and Infantry
  - Marine LAV and AAV
- Rotary Wing Forces
  - Army and Marine Helicopters
- Fixed Wing Forces
  - Navy and Air Force Fighters
- Special Operation Forces
- Coalition Forces
- Fully integrated and task organized

Joint and Coalition combined forces, executing together with Unity of Effort and Unity of Command in a space no larger than *Pentagon South Parking*

Success …

- Solutions to warfighter needs with an S&T solution
  - Predator (ACTD)

  - Counter Radio controlled improvised explosive device Electronic W
    (CREW) IED Electronic Jamming (JUONS)

  - Joint Precision AirDrop System (JPADS) (ACTD)

…and the Future

- Currently SEVEN “Technologically Challenged” JUONS - the “hottest” issues from the warfighter on the front lines
  - Six are related to counter IED
  - One is related to renewable energy
- Currently handled by the JRAC through JIEDDO, appropriate FCB, OSD (AS&C), DSTAG currently not involved
- For discussion: Should the DSTAG become involved with these?
  - Meets monthly - can react quickly
  - Represents DoD-wide S&T agencies, providing increased visibility
  - May be able to provide solutions for these JUONS, stand up Ad-Hoc Technology Focus Team, leverage other R&D/R&E projects, etc.

QUESTIONS/COMMENTS

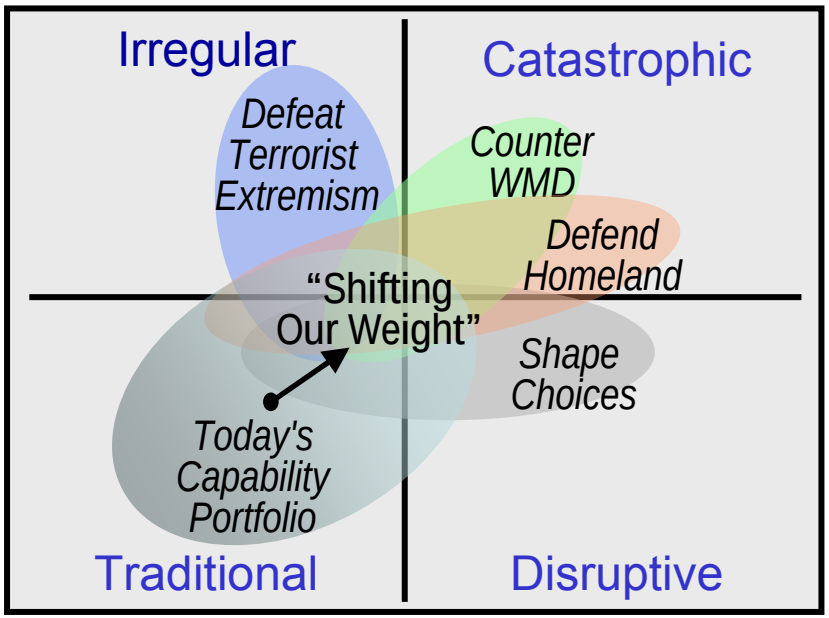
Defense Policy Implications of Global Technology Trends

28 December 2007

Col W. Eric Herr
ODASD Policy Planning

The 2006 QDR Construct

- The 2006 QDR used the "Quad Chart" to analyze the changing nature of warfare



Four Hard Problems

1. **Build partnerships to defeat terrorist extremism**
2. **Defend the homeland in-depth**
3. **Prevent acquisition or use of WMD by hostile actors.**
4. **Shape choices of countries at strategic crossroads**

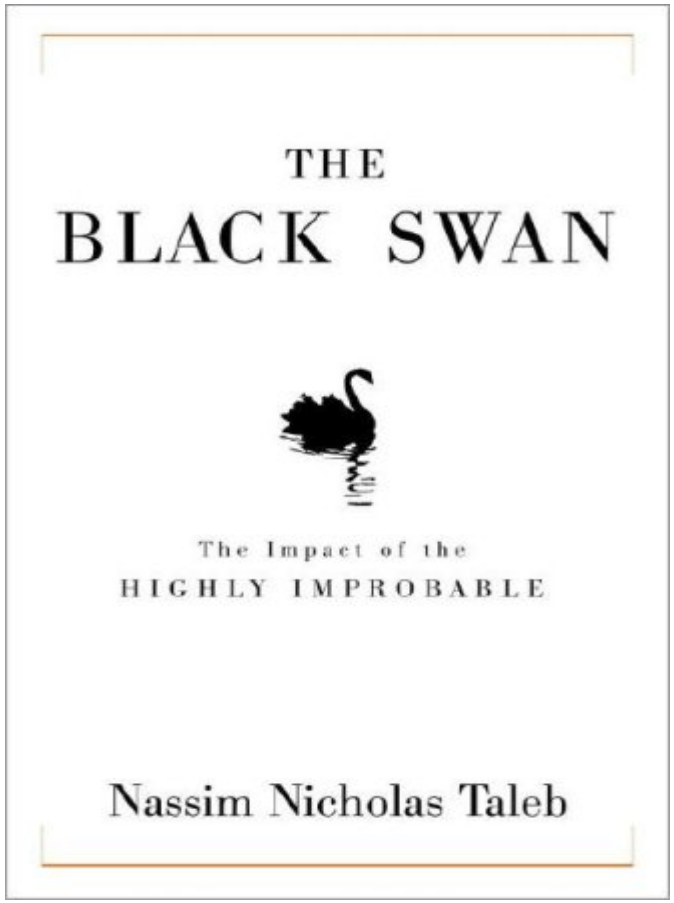
This construct is the basis for our current defense strategy

Understanding the 21st Century

- The “Quad Chart” was the strategic construct for the 2005 National Defense Strategy and 2006 Quadrennial Defense Review
- A new strategic construct might be more appropriate in preparation for the next set of strategic documents
- This model should account for the increasing complexity of the global environment
  - Many non-military factors disrupt international security – we need to better anticipate and respond to these disruptive events

“Black Swan Theory”

Cognitive biases create false expectations of predictability.
Acknowledging uncertainty may allow us to adapt better to unforeseen events.



- “Black Swans”: ***large-impact, impossible to predict, and rare event beyond the realm of normal expectations***
  - 9/11, Google, internet bubble
- “Outside context problem”: ***Problem outside a given groups experience, with an immediate, ubiquitous and lasting impact upon it***
  - Perry’s Black Ships arriving in Japan
- “Accelerating change”: ***increase in rate of technological/ cultural/social progress in history (contrast to linear view)***
  - Accumulation of knowledge, access to knowledge and lowering of transactional barriers to knowledge

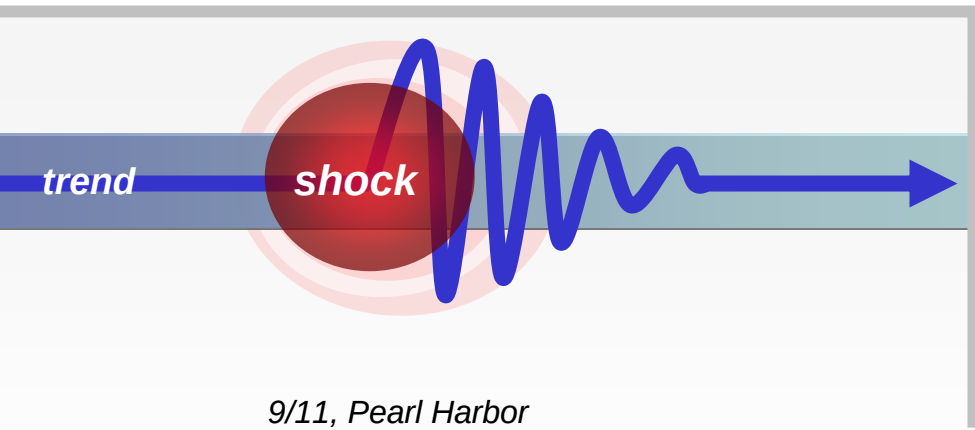
“But there are also "**unknown unknowns**" — the ones we don't know we don't know.**”** *Former Secretary of Defense Donald Rumsfeld, Feb 12, 2002.*

Purpose and Outline

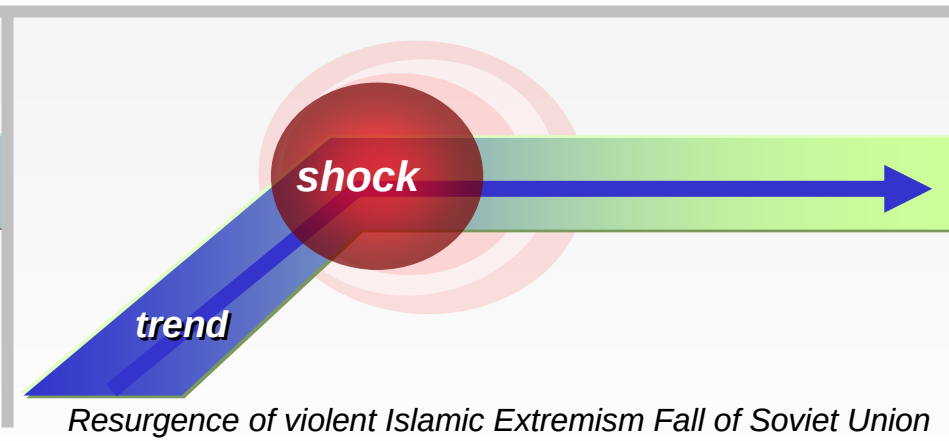
- Purpose
  - Examine U.S. defense and security implications of future technology trends and potential shocks
- Outline
  - Summarize five technology areas by outlining:
    - Current assessment
    - Future trends
    - Defense implications
    - Potential shocks
  - Technology Meta-Trends
  - Way Ahead

Understanding Strategic Shocks

- What is a “strategic shock”?
  - An event that punctuates the evolution of a trend (a discontinuity that either rapidly accelerates its pace or significantly changes its trajectory) and, in so doing, undermines the assumptions on which our current assumptions are based.



9/11, Pearl Harbor



Resurgence of violent Islamic Extremism Fall of Soviet Union

- ❑ Some “strategic shocks” may not surprise us we actively plan for them, both to reduce the risk of their occurrence and to be positioned to act
- ❑ Other “strategic shocks” may catch us unaware and unprepared

The Genesis of Trends and Shocks

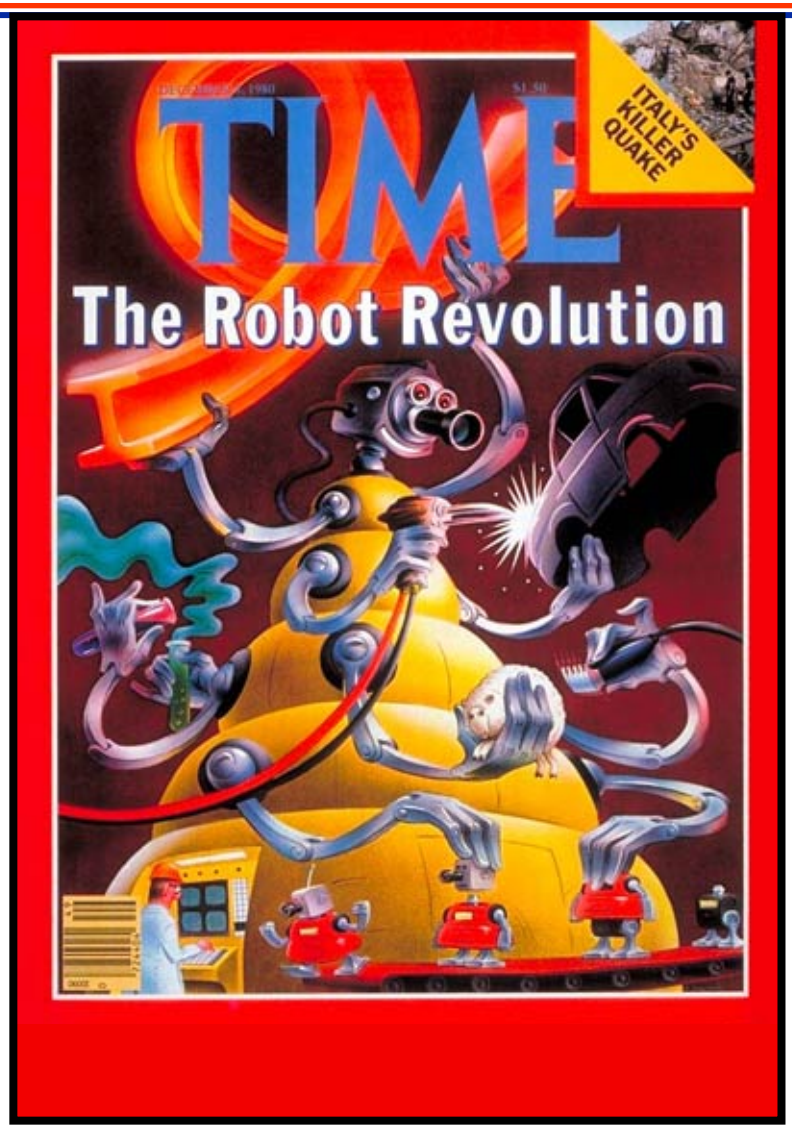
- With hindsight, it is clear that most shocks are the product of long-term trends
- Furthermore, shocks are less disruptive when we have anticipated and responded to the underlying trends
- The challenge is identifying key trends and pre-adaptation for strategic shocks before they occur
  - Reviewing how effective the United States was in foreseeing major trends in the previous century illustrates this effect

Reviewing Major Trends

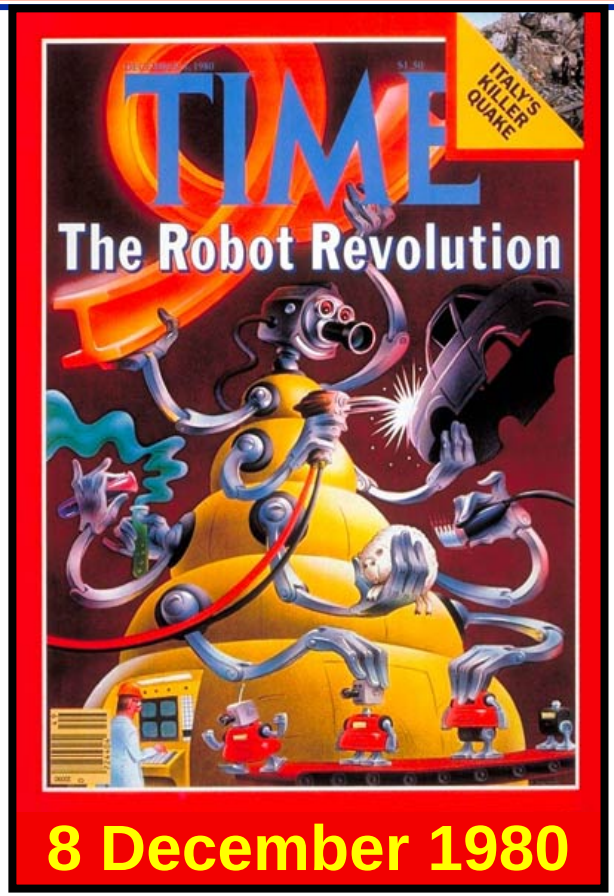
Globalization

Categories	Trend Examples
Conflict	• **Increasing lethality and scope of irregular challenges** • **Military operations in new domains** • ***Rise of China*** — ***Rise of a Near-Peer Competitor*** • ***Cyber war*** — ***Cyber Warfare*** • ***Increasing nuclear proliferation*** — ***Highly Proliferated World***
Demographics	• ***Youth bulge—87% of 10-19 year-olds live in dev. states*** — ***Geopolitical Demographics*** • ***Global aging: The ranks of those over age 60 are growing about 2% each year – 60% faster than the overall population. Primarily affects: Europe, Japan*** • **Urbanization — by 2025, nearly 60% of global population will live in cities**
Economy	• **Growing gap between rich and poor countries** • **Increasing regional and global integration of economies** • **Increasing Asian influence in international markets**
Environment	• ***Disruptions to resource distribution (e.g., water, energy)*** — ***Winners and Losers*** • ***Climate change leading to rise in sea level, changing climatic zones, weather patterns***
Governance	• **State remains dominant unit in international system** • **Strong, but challenged, US leadership in international arenas (e.g., global commons)** • **Increasing influence of the individual, private sector, NGOs on international system** • ***Increasing salience of trans/sub-national identities*** — ***Anthropological Lens on Conflict*** • ***Strong national and sub-national bonds sustained and reinforced through web and remittances*** • **Increasing tension between the "individuals rights" versus "groups rights"**
Science & Technology	• *Technology: Information, Nanotechnology, Bio, Energy, Robotics* — ***Five Revolutions*** • **Increased proliferation of technologies and knowledge**

Technology surprise?



Promises raise expectations – delivery tends to lag



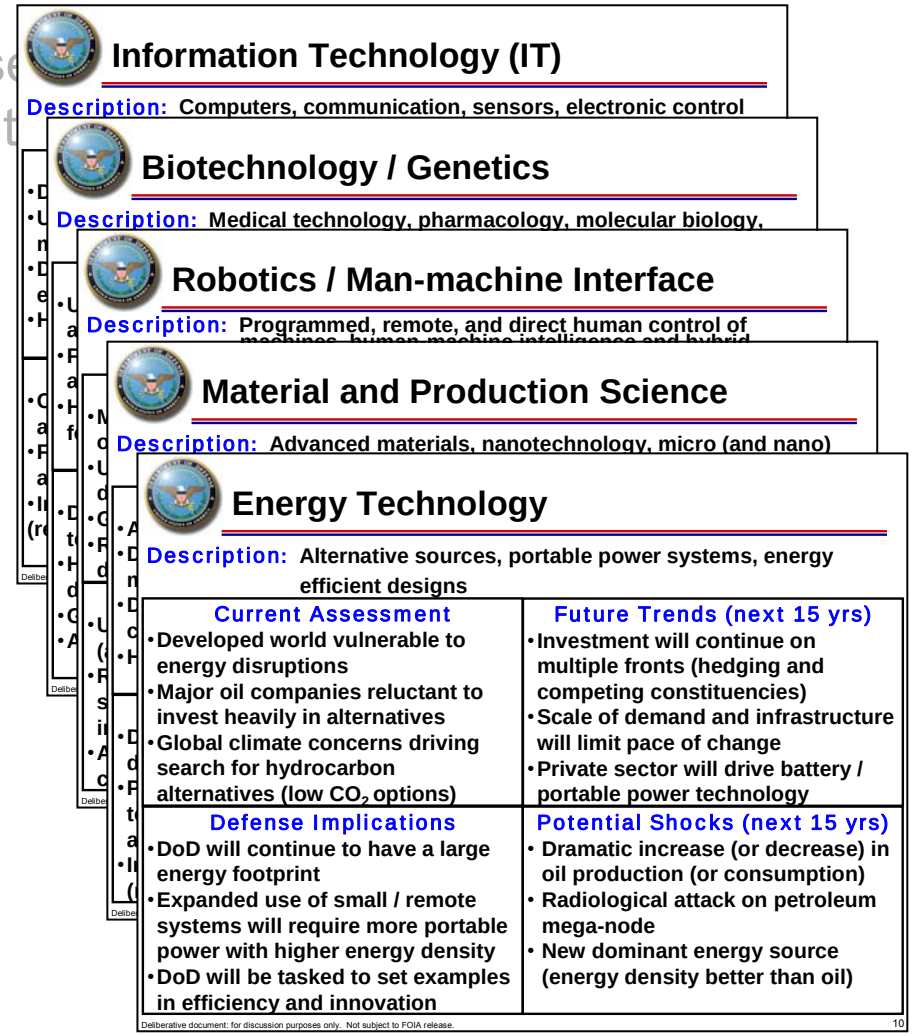
8 December 1980

21 August 1995

- Late delivery desensitizes decision makers to need for change
- True bolts from the blue are possible, but unlikely
- Intersecting revolutions hypothesis

Purpose and Outline

- Purpose
  - Examine U.S. defense and se
    technology trends and potent
- Outline
  - Five technology areas:
    - Current assessment
    - Future trends
    - Defense implications
    - Potential shocks
  - Technology Meta-Trends
  - Way Ahead



Information Technology (IT)

Description: Computers, comm, sensors, networks, electronic control systems, information storage, manipulation, and display

Current Assessment

- **DoD leads in Military C4ISR**
- **U.S. private sector leads global IT markets (rising competitors)**
- **DoD is a market follower in enterprise systems**
- **High investment (and cost) area**

Future Trends (next 15 yrs)

- **Moore's law continues / Bandwidth increases (fiber and wireless)**
- **IT will accelerate change other areas (Bio/Materials)**
- **Decreasing quality / disposability (in hardware and software)**

DoD Implications

- **Continued increasing influence in all mission areas**
- **Free movement of knowledge (blue and red)**
- **Increasing exploitation potential (red and blue)**

Potential Shocks (next 15 yrs)

- **Large-scale SCADA (system control & data acquisition) attack**
- **Accessible quantum encryption**
- **Quantum computing becomes widely available**

Biotechnology / Genetics

Description: Medical technology, pharmacology, molecular biology, biochemistry, bioinformantics, and genetic engineering

Current Assessment

- **U.S. private sectors leads in (most areas)**
- **Free cross-border collaboration and movement of knowledge**
- **High dual-use potential, light footprint, difficult to assess intent**

Future Trends (next 15 yrs)

- **Dramatic cost reductions in gene sequencing equipment**
- **Expanding / accessible databases**
- **Social and cultural norms will limits some advances (in U.S.)**
- **Increasing demands from aging (and wealthy) populations**

DoD Implications

- **DoD has traditionally focused technology on machines (not men)**
- **Human performance has a dramatic effect on all operations**
- **Greatest asymmetric danger**
- **Ambiguous U.S.G. authorities**

Potential Shocks (next 15 yrs)

- **Development of performance degradation technology**
- **Attack with engineered pathogens**
- **2-10X Human Performance Enhancement: sleep, endurance, strength, cognitive ability**
- **Massive failure in food supply**

Robotics / Man-machine Interface

Description: Programmed, remote, and direct human control of machines, human-machine intelligence and hybrid systems

Current Assessment

- **Man (or man-machine) interface often limits system performance**
- **U.S. leads the world in unmanned defense systems**
- **Growing investment (cost) area**
- **Rising powers will apply low cost, dual-use technology**

Future Trends (next 15 yrs)

- **Increased focus on neural function, perception, and cognition**
- **Expansion of autonomous systems and virtual presence**
- **Rapidly emerging threats**
- **New vulnerability sets (links, data, control)**

DoD Implications

- **Unmanned systems have proven (and increasing) value**
- **Remotely-manned and hybrid systems can be used in increasingly complex missions**
- **Amputation / neurological casualties from IEDs**

Potential Shocks (next 15 yrs)

- **Fused human-machine intelligence**
- **Low cost, swarming systems or autonomous precision attack systems**

Material and Production Science

Description: Advanced materials, nanotechnology, micro (and nano) electromechanical devices, prototyping, production

Current Assessment

- **Area of U.S. competitive advantage**
- **DoD is the global leader in existing mission areas (air-sea-land-space)**
- **DoD will follow in expanding commercial markets**
- **High dual-use potential**

Future Trends (next 15 yrs)

- **Rapidly expanding nano and MEMS (commoditization)**
- **Increasing focus on MEMS/NEMS**
- **Continued convergence of IT, robotics, and bio technology**
- **Increased emphasis on reducing development to market timelines**

DoD Implications

- **Dual-use makes this technology difficult to control**
- **Proliferation will reduce DoD's technical edge and expand asymmetric attack options**
- **Increased reliability / reduced cost (must pair with agile acquisition)**

Potential Shocks (next 15 yrs)

- **Proliferation of highly energetic materials**
- **Invasive nano particles/NEMS used as medical or biological agents; delousing**
- **Sensor dust, ubiquitous sensing**
- **Broad-band metamaterials**

Energy Technology

Description: Alternative sources, portable power systems, energy efficient designs

Current Assessment

- **Developed world vulnerable to energy disruptions**
- **Major oil companies reluctant to invest heavily in alternatives**
- **Global climate concerns driving search for hydrocarbon alternatives (low CO_2 options)**

Future Trends (next 15 yrs)

- **Investment will continue on multiple fronts (hedging and competing constituencies)**
- **Scale of demand and infrastructure will limit pace of change**
- **DoD must will drive battery / portable power technology**

DoD Implications

- **DoD will continue to have a large energy footprint**
- **Expanded use of small / remote systems will require more portable power with higher energy density**
- **DoD will be tasked to set examples in efficiency and innovation**

Potential Shocks (next 15 yrs)

- **Dramatic increase (or decrease) in oil production (or consumption)**
- **Radiological attack on petroleum mega-node**
- **New dominant energy source (energy density better than oil)**

An information age Pearl Harbor?

NO….but this guy is far cry from Imperial Japan

George Hotz, 17, of Glen Rock, New Jersey holding the iPhone® that he separated from the AT&T network and used on the T-Mobile Network. Career goal: hack the human brain

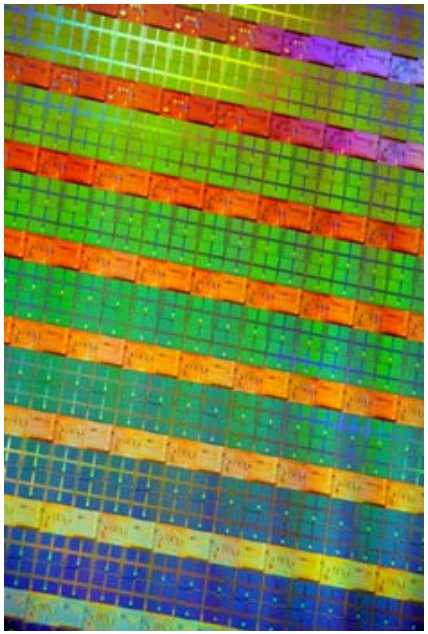
- Apple and AT&T released the iPhone on 29 June
- An exclusive agreement guaranteed the iPhone could only be used on AT&T's mobile network
- Hotz spent approximately 500 hours working on his "summer project"
- The hack was announced on 24 August.

- AT&T - market cap: $245B
  - annual revenue: $90B
- Apple - market cap: $117B
  - annual revenue: $23B
- Hotz - PRICELESS

This is the new asymmetry—victory goes to the agile and innovative

Recent Developments

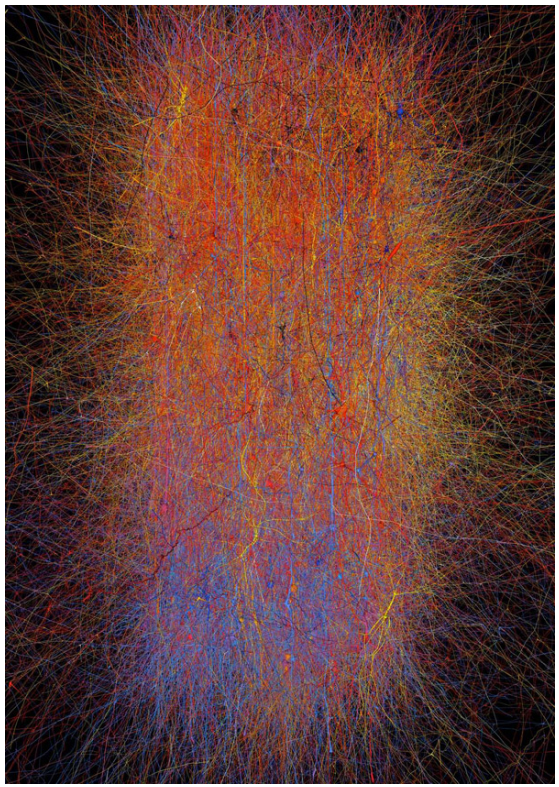
Hafnium oxide: 45nm transistors



A beam of light travels less than a tenth of an inch during the time it takes a 45nm transistor to switch on and off.

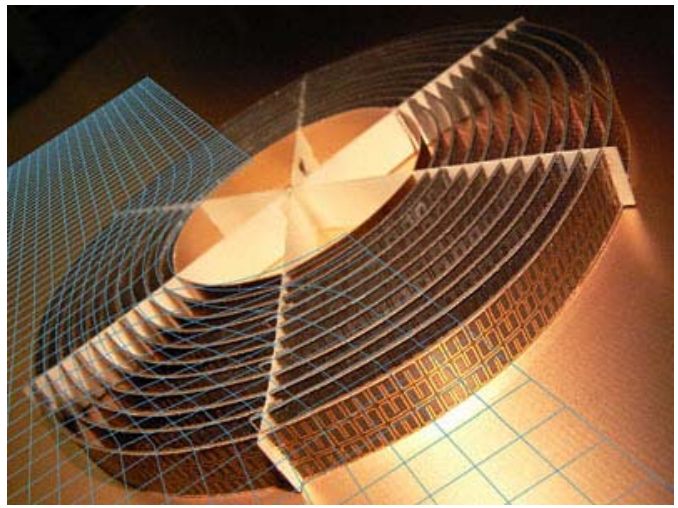
Surprise revival of Moore's law just before anticipated end of silicon chip progress

Supercomputer neuro-map: 10,000 neurons and 30 million connections

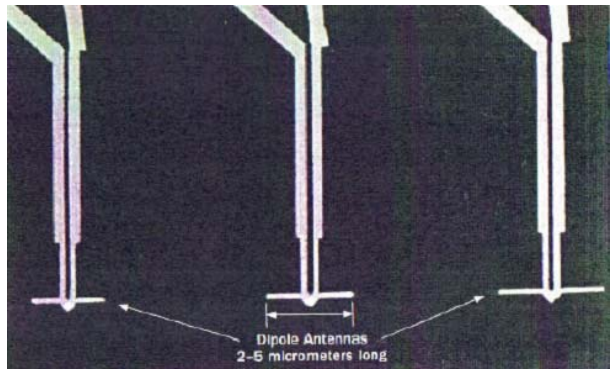


Scientists are now planning to model the entire human brain within just 10 years - "fantastic acceleration in brain research"

Metamaterials: 2D microwave "invisibility cloak"



From theory to tech demonstration in 5 months



Nano Antennas: receiving infrared RF signals

Could lead to sensors a million times more sensitive than current technology. First predicted in 1960s

Age of Scientific Innovation

- Paradigm-shifting scientific discoveries have historically occurred at a young age
  - Newton – 24; Darwin – 22; Einstein - 26
- Mid-career scientists are now considered to be most productive--if measured by lists of publications
  - May be due to longer training phases, accumulative advantage, focus on acceptance vs. discovery
- Scientific and technological discovery and innovation are not limited to academic publications and PhD's.
  - Some of the most successful innovators of recent decades have been college drop-outs
    - Bill Gates, Steve Wozniak, Michael Dell
  - Some of the most threatening innovators have been under the age of twenty-five
    - Global Bot "Mastermind" – 18 year old alleged by FBI to lead effort of infecting and controlling over a million computers world-wide
    - Godfather of Cyber Terrorism – recently arrested 22 year old Al Qaeda internet operative
    - World's Most Famous Hacker – Kevin Mitnick, who broke into DEC computers to steal their operating system development software at 16

Technology Meta-Trends (1)

- **Technological change is accelerating**
  - Accelerating application of knowledge and technology
    - Past – Change limited by state-based science, technology, capital
    - Future – Change limited by interest, policy, and law
  - Increasing rate of "paradigm shifts"
  - Invention/innovation speeds up invention/innovation (feedback loop)
- **U.S.'s technological advantage eroding**
  - Free-flowing factors of production: S&T, labor, capital
  - Nation state risk aversion: bureaucratic, conservative governance
  - U.S. economy may fall to world's 3rd largest in latter half of century
  - Increasing number of 6-Σ individuals migrating into productive sector in China/India
- **Discovery may rely more on global collaboration than years of graduate study**
  - Innovation as a "young man's game" (Planck) vs. the realm of experienced, qualified experts

Technology Meta-Trends (2)

- "Silicon" computing power on path to exceed "carbon" computing power
  - Implications of machines surpassing computing power of human brain
- Super-empowerment and new global actors
  - Technology investment geared to empower the individual - personal transportation, communications, finance, entertainment, health care
  - Proliferation of "new" technologies in the hands of agile adversaries
    - Nation-state's destructive power available to single decision-makers
    - Growing access to converging technologies (speed, cost, scope)
- Unforeseeable technology innovation – the third step
  - How will technology used in ways we cannot predict?
  - How will technology change the way we think and organize?
- Perception U.S. less open to foreign students and scholars
  - Enrollment declined in 2003-07 for first time since 1971; however, 2006-07 school year saw increase
  - Post-9/11 restrictions make European institutions seem more attractive

Recommendations – People

- Make government lab resources more widely available to University researchers and develop programs to continue those relationships
  - Expand Summer Faculty Research Program and Sabbatical Leave Program (ASEE); Post-doctoral fellowship (ASEE); Defense Science and Engineering Graduate Fellowships
- Develop and expand existing innovative hiring, employment, and contracting authorities
  - Intergovernmental Personnel Act, Highly Qualified Experts, industry fellowships, SMART program, NSEP
  - Develop attractive rotational career paths and collaborative opportunities
- Partner with research and development competitions
  - Odyssey of the Mind, Exploravision, Science Olympiad, FIRST, Idea to Project

Recommendations – Horizon Scanning

- Enhance organizations with staff and methodology to alert senior leaders to disruptive trends, shocks, and potential mitigation
  - Build technology intelligence program that includes technology scanning and collaboration with partners, private sector – X2 as a model
  - Link tech intelligence to technology red teaming and blue teaming process (DDR&E)
    - Technology war-gaming / Identify indicators and red lines
  - Integrate operational perspectives by recruiting and strategically placing/detailing “technology scouts”
    - Services and Defense Agencies
    - Intern, externs, fellows, and gray beards
  - Develop protocols to raise major issues to senior leadership
  - Share information and increase visibility across government

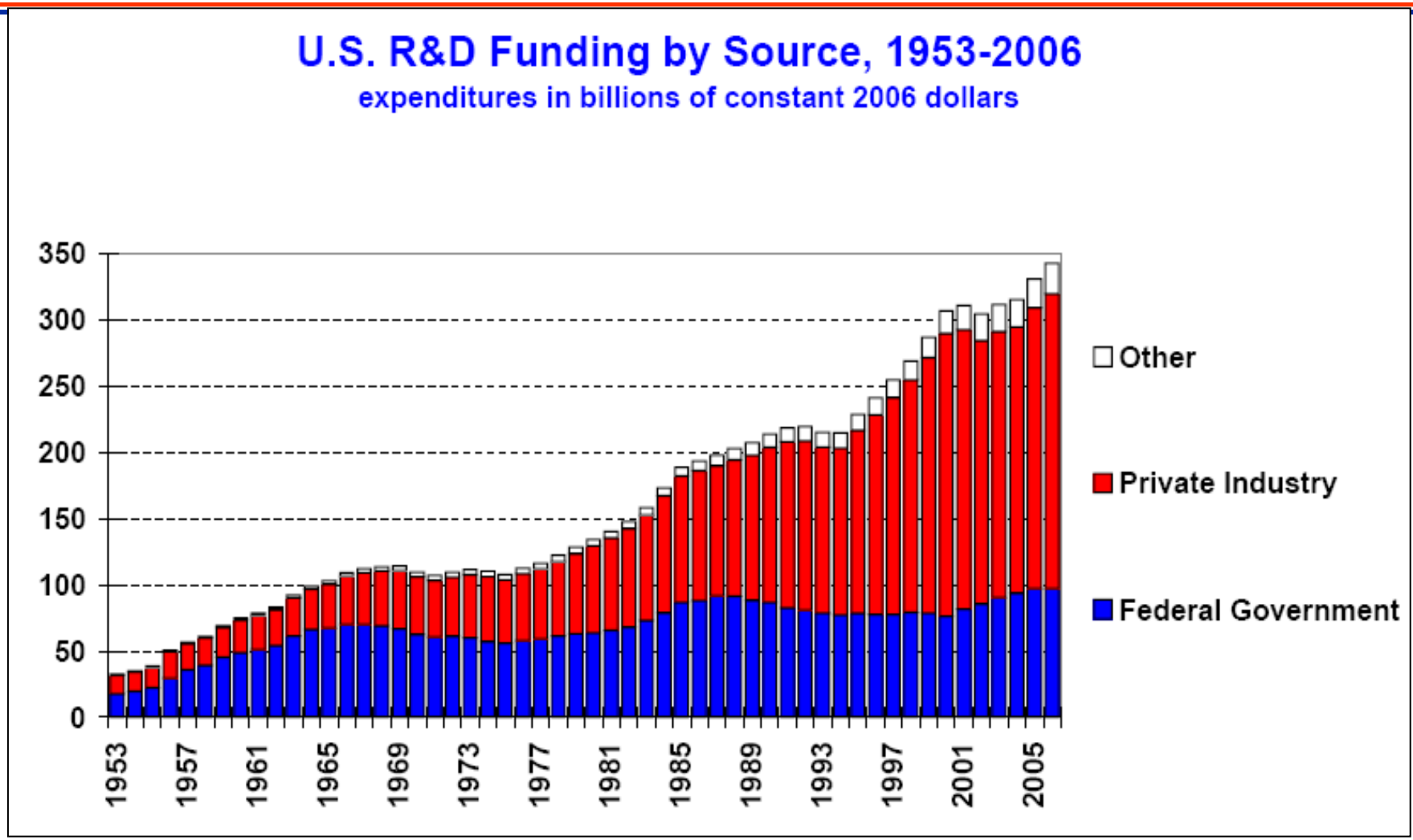
Recommendations – Leveraged Innovation

- Sponsor technology research and “challenges” that focus on interdisciplinary research and applications
- Examples: DARPA challenges, MURIs, tech venture funds that
  - Open doors for groups pursuing innovative research that would not/could not pursue access to DoD market
  - Award winners, dramatic innovators – continue relationship high potential teams
  - Provide seed money to promising teams (tech CERP) for ideas
- Example focus areas:
  - Energy: portable power; domestically sources compatible with legacy equipment and infrastructure; carbon neutral / carbon sequestration
  - TTL: “Naked man” problem; tag at a distance; stand-off detection of fissile material

Questions?

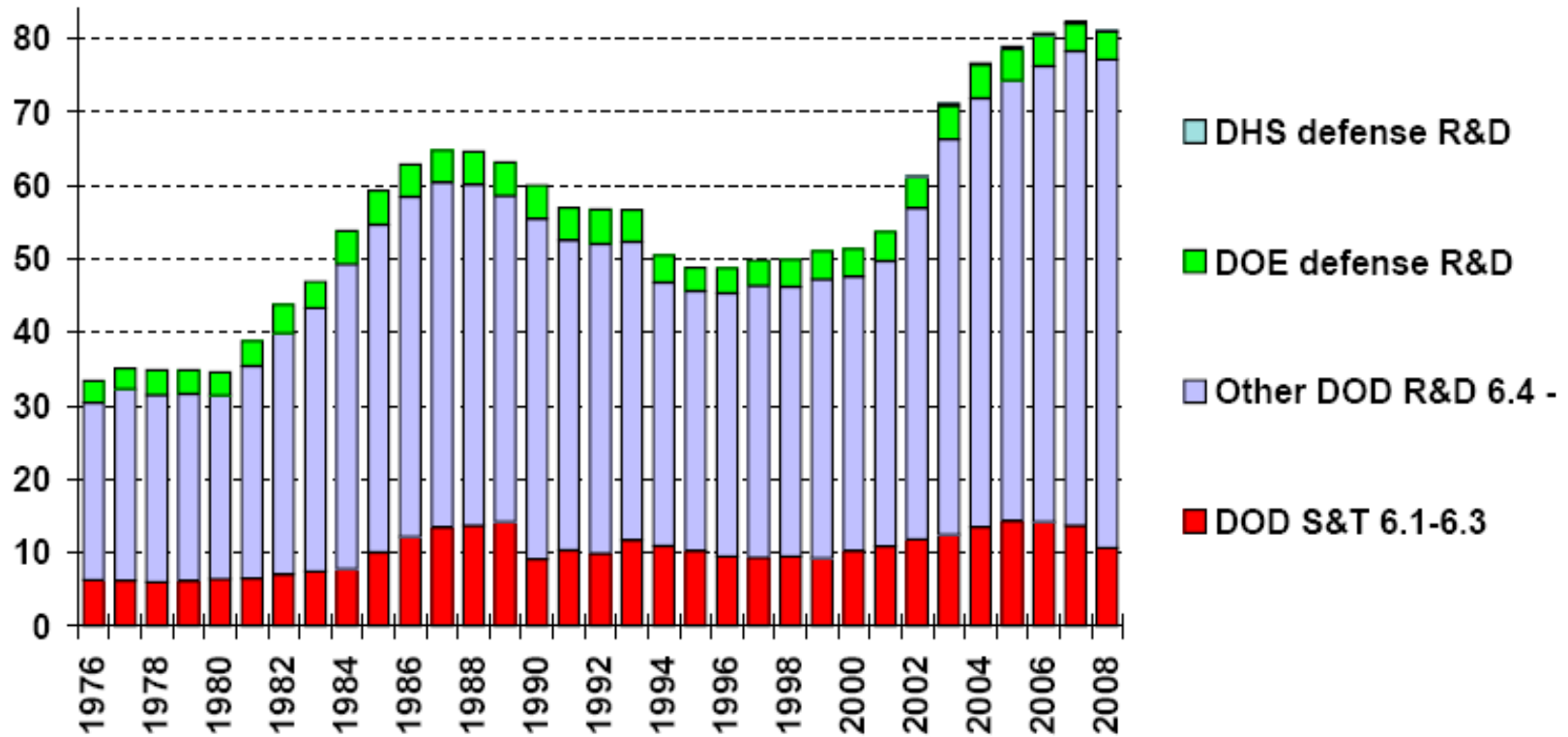
BACKUPS

Decreasing Weight of USG Investment

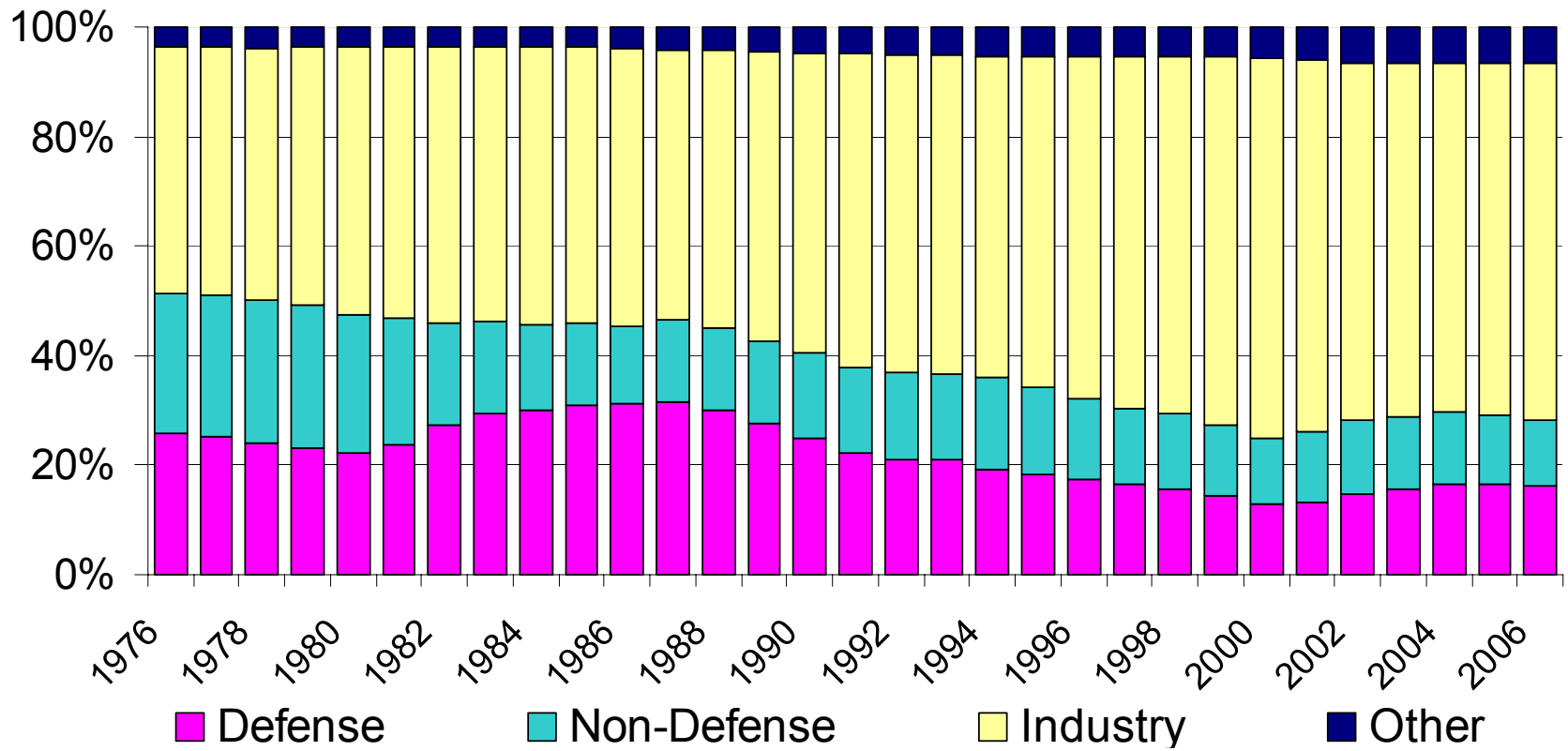


Source: NSF, Division of Science Resources Statistics. (Data for 2005 and 2006 are preliminary.)

Defense R&D

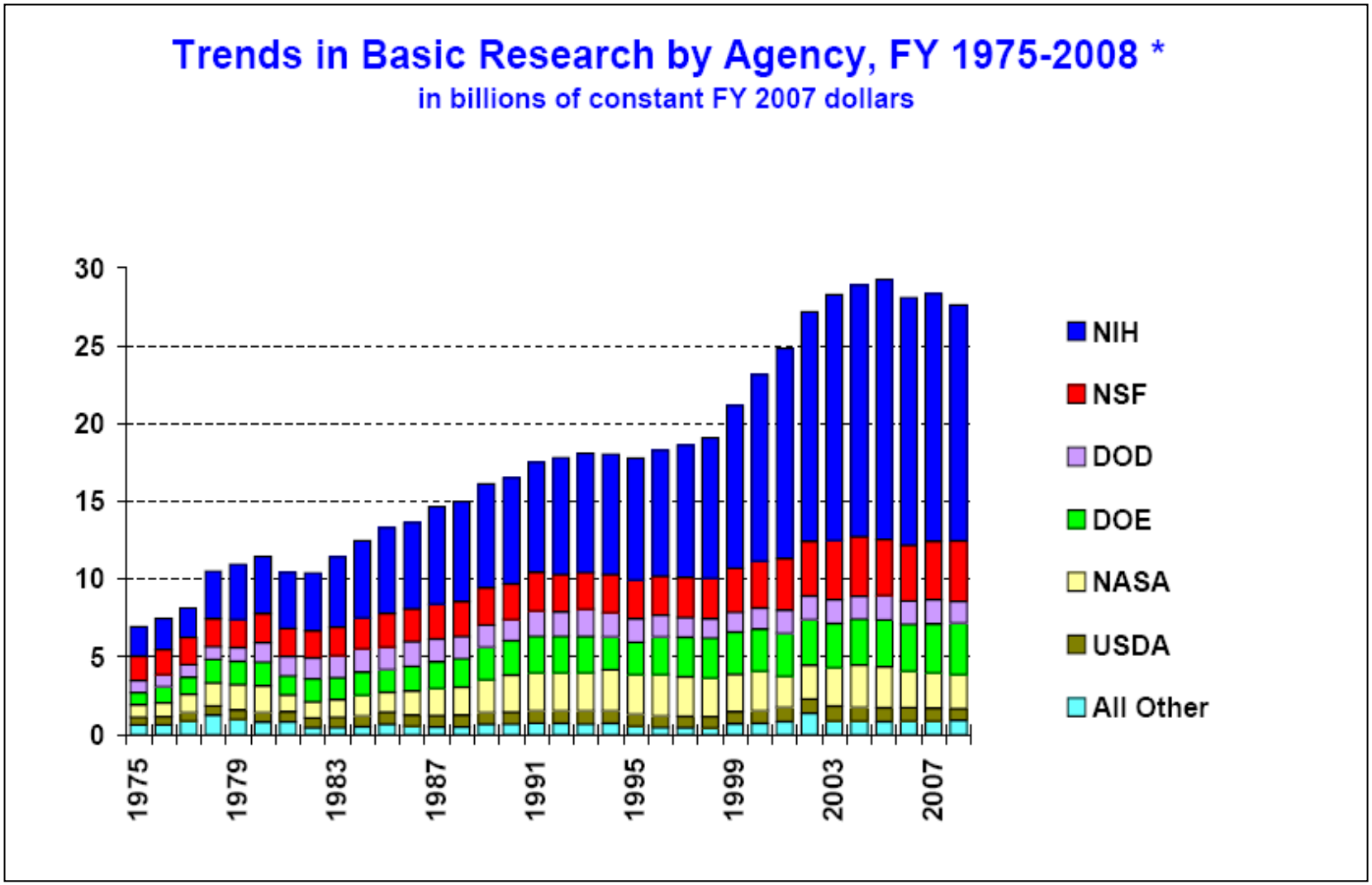

Trends in Defense R&D, FY 1976-2008 *
in billions of constant FY 2007 dollars
80
70
60
50
40
30
20
10
0
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
DHS defense R&D
DOE defense R&D
Other DOD R&D 6.4 -
DOD S&T 6.1-6.3

30 Year Trend in U.S. R&D Investments

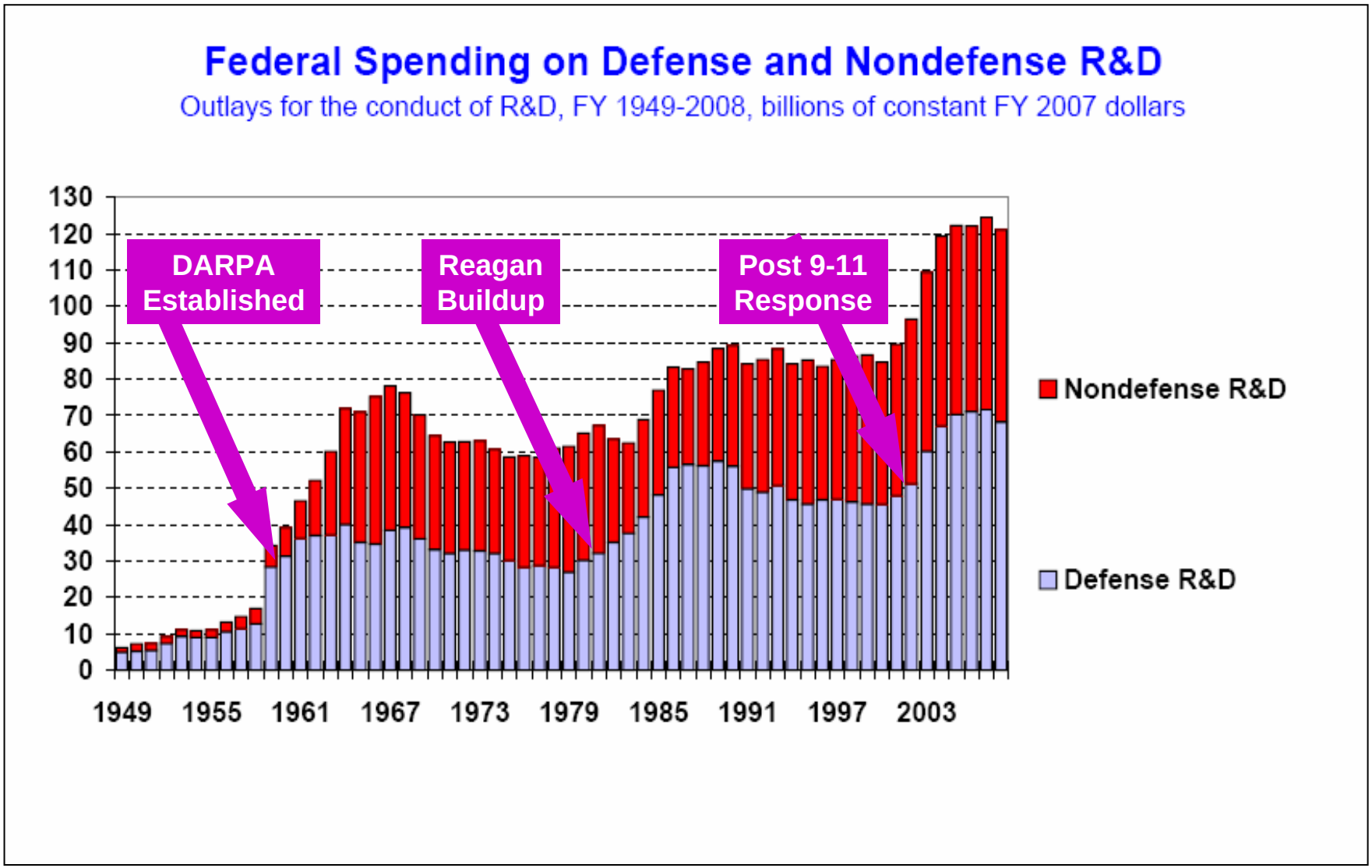


- DoD R&D effort down from 26% to 16% of U. S. total
- Total Federal effort down from 51% to 28%
- Industry R&D effort up from 45%to 65%
- Non-profits, educational institutions, state, and local up from 4% to 7%

Basic Research (BA 1)



DoD R&D is about half of U.S.G. total



The Importance of Horizon Scanning

- Inductive logic – necessary and overwhelmingly attractive
  - *The sun will rise tomorrow…*
  - *78 percent of Americans support…*
  - *The top mutual performing fund for the last ten years…*
- The law of large numbers
  - Regression analysis, curve fitting, and forecasting
  - Sufficient and random sampling of independent variables
- The farmer and the chicken
  - When do we have enough information?
  - Should we constantly challenge our current ideas and theories?
  - Should we take every day one day at a time?

One Effect of Quantum Computing:
Ability to Break RSA Public Key Encryption

The RSA algorithm was invented in 1977; it is a *computationally secure* based on four parameters: P, Q, E, and D

- –*P* and *Q*, two large prime numbers
- –*E* such that *E* is greater than 1, *E* is less than *PQ*, and *E* and *(P-1)(Q-1)* have no prime factors in common
- –*D* such that (DE - 1) is evenly divisible by (P-1)(Q-1)

The encryption function is *C = (T^E) mod PQ* (C is the ciphertext)

- –The *public key* is the pair *(PQ, E)*

The decryption function is *T = (C^D) mod PQ* (T is the plaintext)

- –The *private key* is the number *D*

One can publish the public key freely

- –There are no practical methods of calculating *D*, *P*, or *Q* given only *(PQ, E)*
- –If *P* and *Q* are each 1024 bits long, the sun will burn out before the most powerful classical computers can factor PQ into *P* and *Q* *(quantum computer could do it in minutes)*

Quantum computers undo the computational security of public key encryption

Research & Development Budget Categories

Budget Activity 1: Basic Research

Budget Activity 2: Applied Research (S&T)

Budget Activity 3: Advanced Technology Development (ATD)

Budget Activity 4: Advanced Component Development and Prototypes (ACD&P)

Budget Activity 5: System Development and Demonstration (SDD)

Budget Activity 6: RDT&E Management Support RDT&E

Budget Activity 7: Operational System Development

Budget Activities 1 through 3 are often collectively referred to as Science and Technology (S&T)

Budget Activities 4,5 and 7 are normally associated with acquisition programs

Budget Activity 6 funds RDT&E infrastructure

Research & Development Budget Categories

Budget Activity 1: Basic Research, the systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind (formerly known as 6.1)

Budget Activity 2: Applied Research, the systematic study to understand the means to meet a recognized and specific need (formerly known as 6.2)

Budget Activity 3: Advanced Technology Development (ATD) includes development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment (formerly known as 6.3)

We Don't Know What We Don't Know

"By 2020, organic electronics should provide for increased brightness of widespread lighting systems and displays."

RAND, *The Global Technology Revolution 2020*
(Released in 2006)

Super-vivid, super-efficient displays
New OLED displays for mobile gadgets are poised for debut in U.S. and European markets

Technology Review
November 06, 2006

Sony: 1,000,000:1 OLED TV on sale in 2007

Engadget
Posted 12 April 2007

Performance Remediation

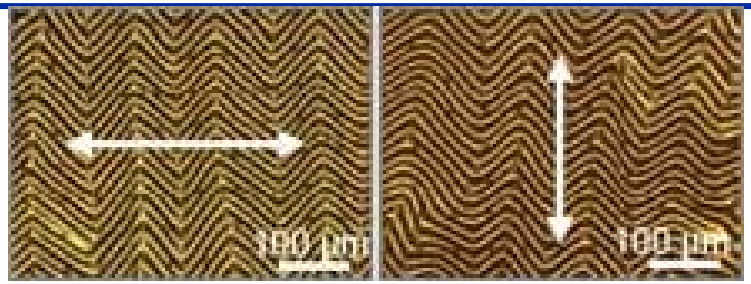
World First Power Ankle

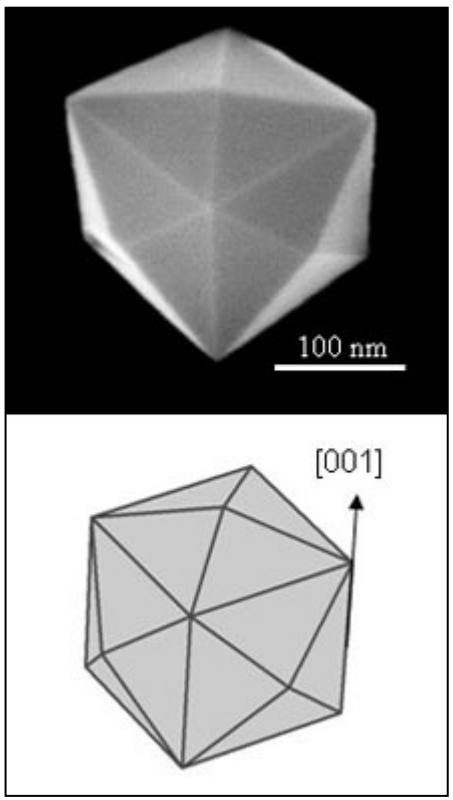
- **Developed at biomechatronics group at the MIT Media Lab**
- **Small battery-powered motor mimics the energy-storage capacity of the human ankle**
- **Power-assisted spring propel the foot forward as it pushes off the ground**
- **about 20 percent more efficient than past devices**
- **Tested in partnership with Military Amputee Research Program**

Brain-Machine Interface

- Emotiv Systems electro-encephalograph (EEG) cap
- On sale to software developer's
- Used to build games that use the electrical signals from a player's brain to control the on-screen action
- Could be useful in virtual-world games, such as Second Life
- Commercial successful remains uncertain

Current Materials Research





Sheets of Stretchable Silicon

Researchers have shown that ultrathin sheets of silicon can stretch in two dimensions--opening up the possibility of electronic eyeballs and smart surgical gloves.

Technology Review
May 15, 2007

Better Catalysts for Fuel Cells

Nanoparticles with a completely new shape may lead to cheaper catalysts that could make many experimental-energy technologies more practical.

Technology Review
May 15, 2007

Public Companies with $150B* in Revenue (why oil matters so much)

$366.24B	Exxon Mobil Corporation engages in the exploration, production, transportation, and sale of crude oil and natural gas.	Irving, TX
$355.38B	Wal-Mart Stores, Inc. operates retail stores in various formats worldwide.	Bentonville
$318.13B	Royal Dutch Shell plc, through its subsidiaries, engages in the exploration, production, and trading of various energy resources worldwide.	The Hague
$263.89B	BP p.l.c. provides fuel for transportation, energy for heat and light, retail services, and petrochemicals products.	London
$209.84B	Toyota Motor Corporation operates in the automotive industry worldwide.	Toyota City
$204.78B	DaimlerChrysler AG engages in the development, manufacture, distribution, and sale of automotive products, including passenger cars, trucks, vans, and buses worldwide.	Stuttgart
$191.74B	General Motors Corporation and its subsidiaries engage in the development, production, and marketing of cars, trucks, and parts worldwide.	Detroit
$189.82B	Chevron Corporation operates as an integrated energy company worldwide.	San Ramon
$176.14B	TOTAL S.A., together with its subsidiaries, operates as an integrated oil and gas company worldwide.	Paris
$167.21B	General Electric Company (GE) is a diversified industrial corporation.	Fairfield , CT
$164.72B	Ford Motor Company and its subsidiaries design, develop, manufacture, and service cars, trucks, and parts worldwide.	Dearborn, MI
$162.22B	ConocoPhillips operates as an integrated energy company worldwide.	Houston, TX
$152.55B	AXA, through its subsidiaries, provides global financial protection and asset management services.	Paris
$141.44B	China Petroleum & Chemical Corporation, through its subsidiaries, operates as an integrated oil and gas, and chemical company in the People's Republic of China and Hong Kong.	Beijing

U.S. Science and Math Literacy

Average science score of eighth grade students, by country: 2003

Country	Score
International average	473
Singapore	578
Chinese Taipei	571
South Korea	558
Hong Kong, China	556
Estonia	552
Japan	552
Hungary	543
Netherlands	536
United States	527
Australia	527
Sweden	524
Slovenia	520
New Zealand	520
Lithuania	519
Slovak Republic	517
Belgium	516
Russian Federation	514
Latvia	512
Scotland	512
Malaysia	510
Norway	494
Italy	491
Israel	488
Bulgaria	479
Jordan	475
Moldova	472
Romania	470
Serbia	468
Armenia	461
Iran	453
Macedonia	449
Cyprus	441
Bahrain	438
Palestinian National Authority	435
Egypt	421
Indonesia	420
Chile	413
Tunisia	404
Saudi Arabia	398
Morocco	396
Lebanon	393
Philippines	377
Botswana	365
Ghana	255
South Africa	244

Average higher than U.S. average
Average not measurably different from U.S. average
Average lower than U.S. average

SOURCES: P. Gonzales, J.C. Guzman, L. Partelow, E. Pahlke, L. Jocelyn, D. Kastberg, and T. Williams, *Highlights From the Trends in International Mathematics and Science Study (TIMSS) 2003*, U.S. Department of Education, National Center for Education Statistics, NCES 2005-005, table 9 (2004); and data from International Association for the Evaluation of Educational Achievement, *Trends in International Mathematics and Science Study (TIMSS)* (2003).

Science and Engineering Indicators 2006

Average mathematics literacy score of 15-year-old students, by country: 2003

Country	Score
OECD countries	500
Finland	544
South Korea	542
Netherlands	538
Japan	534
Canada	532
Belgium	529
Switzerland	527
New Zealand	523
Australia	524
Czech Republic	516
Iceland	515
Denmark	514
France	511
Sweden	509
Austria	506
Germany	503
Ireland	503
Slovak Republic	498
Norway	495
Luxembourg	493
Poland	490
Hungary	490
Spain	485
United States	483
Portugal	466
Italy	466
Greece	445
Turkey	423
Mexico	385
Non-OECD countries	
Hong Kong, China	550
Liechtenstein	536
Macao-China	527
Latvia	483
Russian Federation	468
Serbia and Montenegro	437
Uruguay	422
Thailand	417
Indonesia	360
Tunisia	359

Average higher than U.S. average
Average not measurably different from U.S. average
Average lower than U.S. average
OECD = Organisation for Economic Co-operation and Development

SOURCES: M. Lemke, A. Sen, E. Pahlke, L. Partelow, D. Miller, T. Williams, D. Kastberg, and L. Jocelyn, *International Outcomes of Learning in Mathematics Literacy and Problem Solving: PISA 2003 Results From the U.S. Perspective: Highlights*, U.S. Department of Education, National Center for Education Statistics, NCES 2005-003, table 2 (2004); and data from OECD, Programme for International Student Assessment (PISA) (2003).

Science and Engineering Indicators 2006

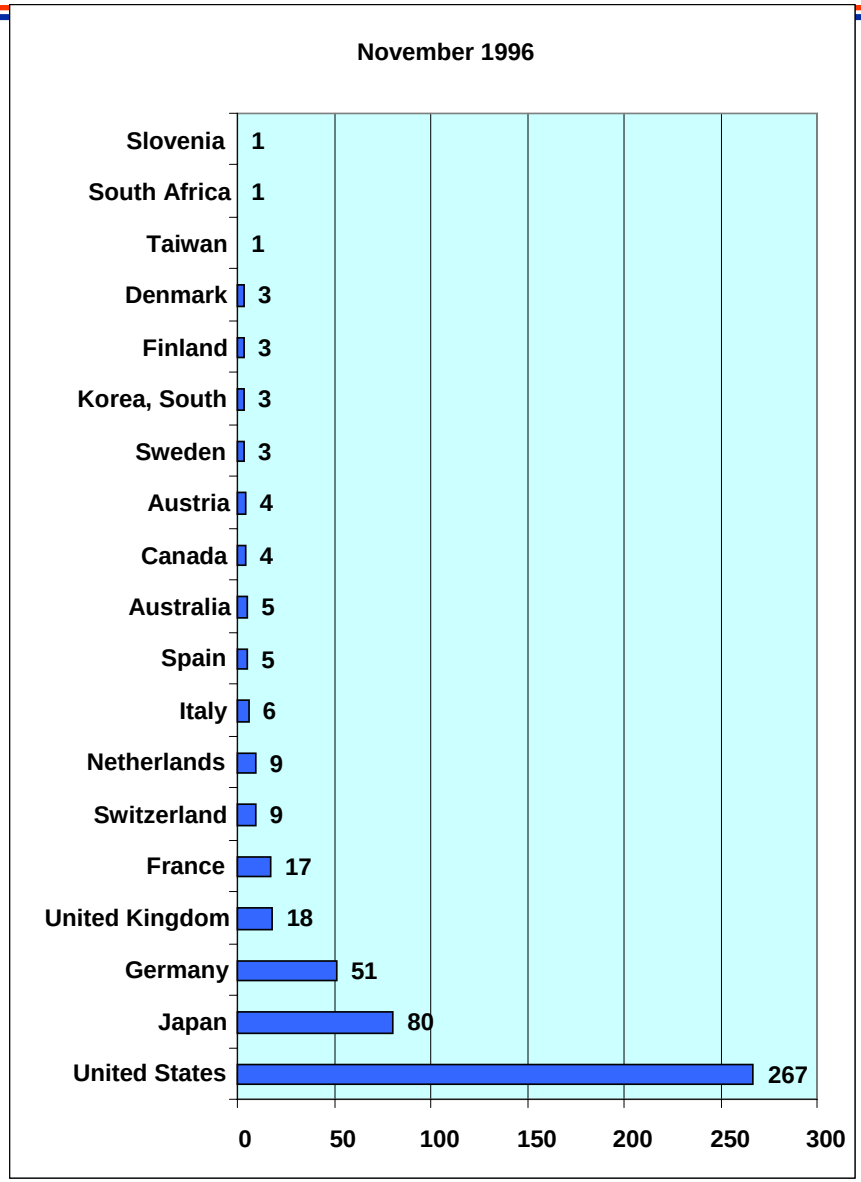
Rise of China's R&D Efforts

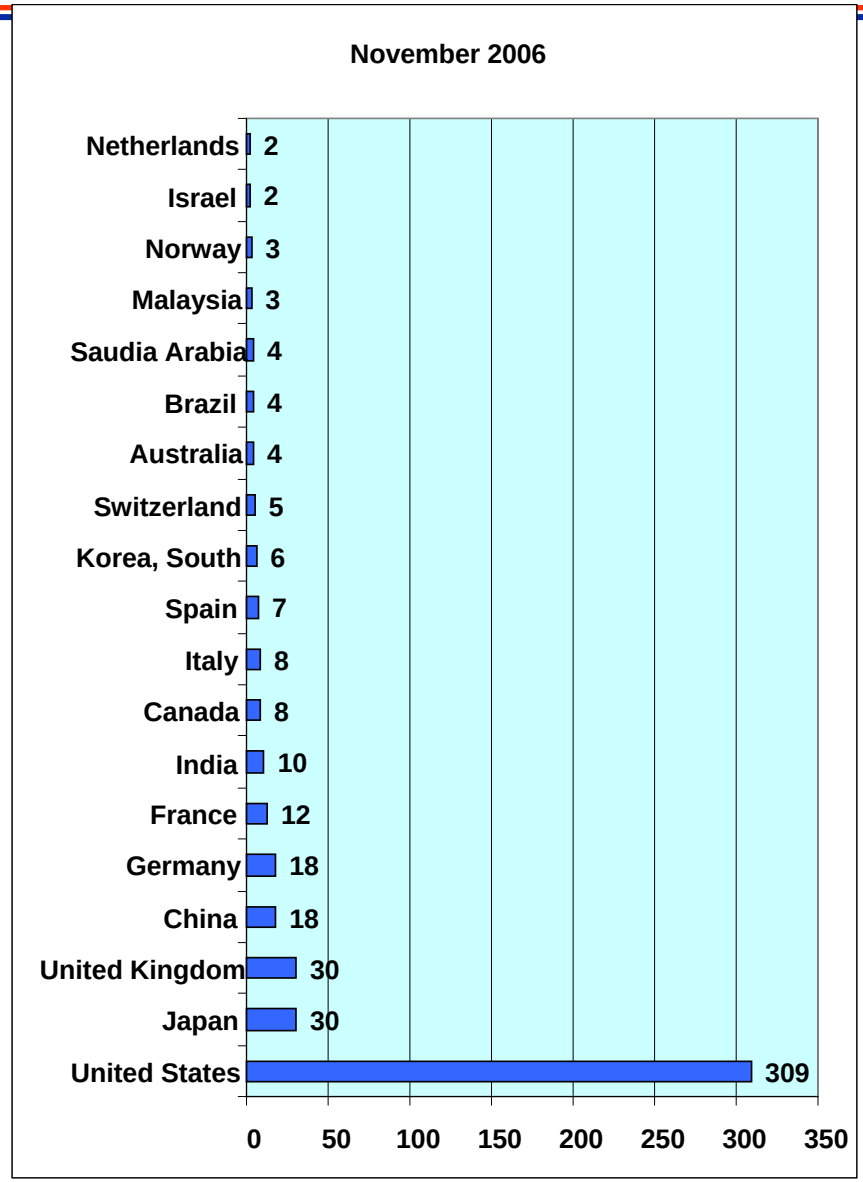
- U.S. Leads World in R&D Spending, China Moves to 3rd Place

  The United States continues to lead the world in R&D with 34 percent of world R&D spending in 2005, according to data from the OECD. U.S. industry, government and other sectors spend more on R&D than the entire EU combined. The U.S. share has declined from 40 percent during most of the 1990s. China has increased its R&D performance dramatically in recent years and is just narrowly the 3rd largest performer of R&D (adjusted for purchasing power), and will overtake 2nd place Japan in 2006.
- In scientists and engineers employed in R&D activities, China is already 2nd in the world behind only the United States.

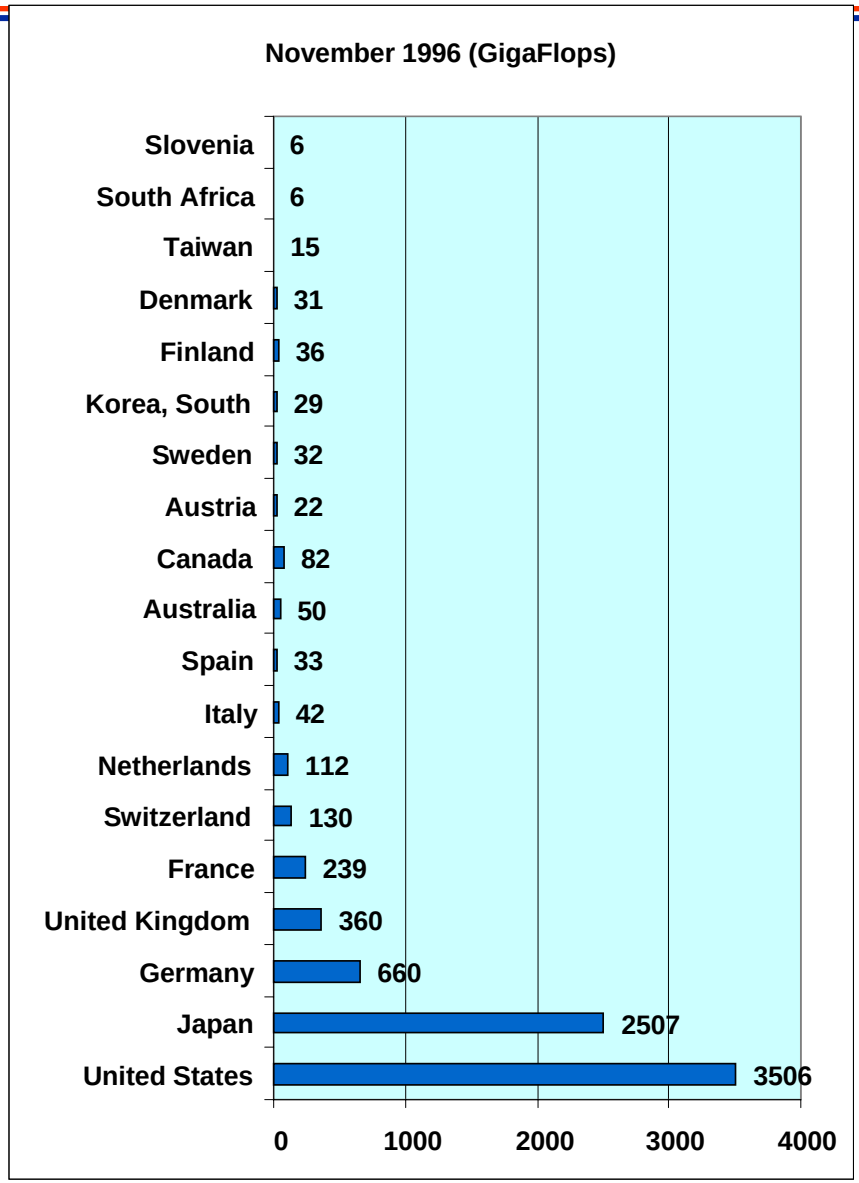
May 15, 2007
American Association
for the Advancement of Science

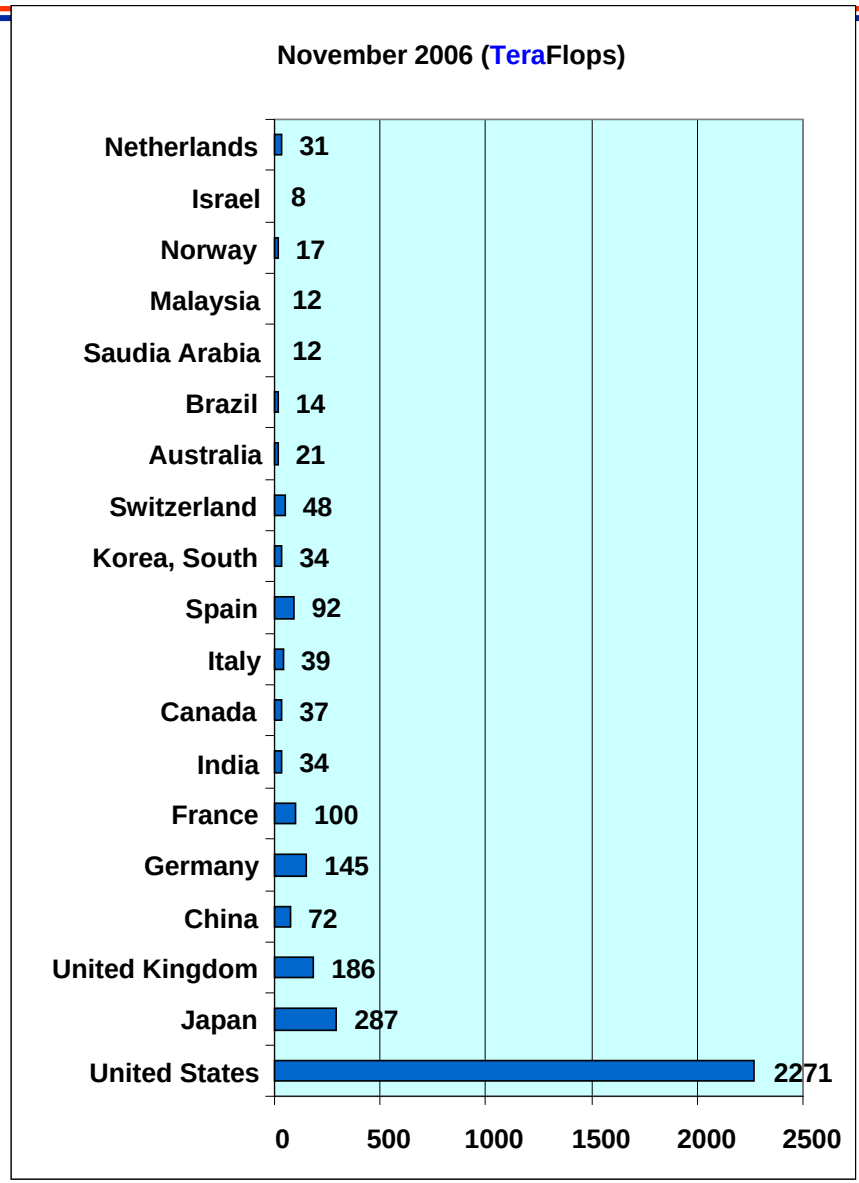
Super Computers: Number of Top 500





Super Computers: Processing





Selected Sources

- *Science and Engineering Indicators 2006.* Two Volumes

  National Science Board
  National Science Foundation, 2006

- *21th Century Strategic Technology Vectors*

  Defense Science Board, 2006

- *Proceedings*, Australia-U.S. Bilateral Emerging Technology Conference

  May, 2007

- *Converging, Combining, Emerging*

  Dr. George Poste, Presentation,
  Highland Forum XXXII

- *Steering Group Report: Brain Science as a Mutual Opportunity for the Physical and Mathematical Sciences, Computer Science, and Engineering*

  National Science Foundation
  August 2006

- *Globalization, Biosecurity, And The Future of The Life Sciences*

  Institute of Medicine and National Research
  Council of the National Academies, 2006

- *Human Performance Modification Collaboration Workshop Report*

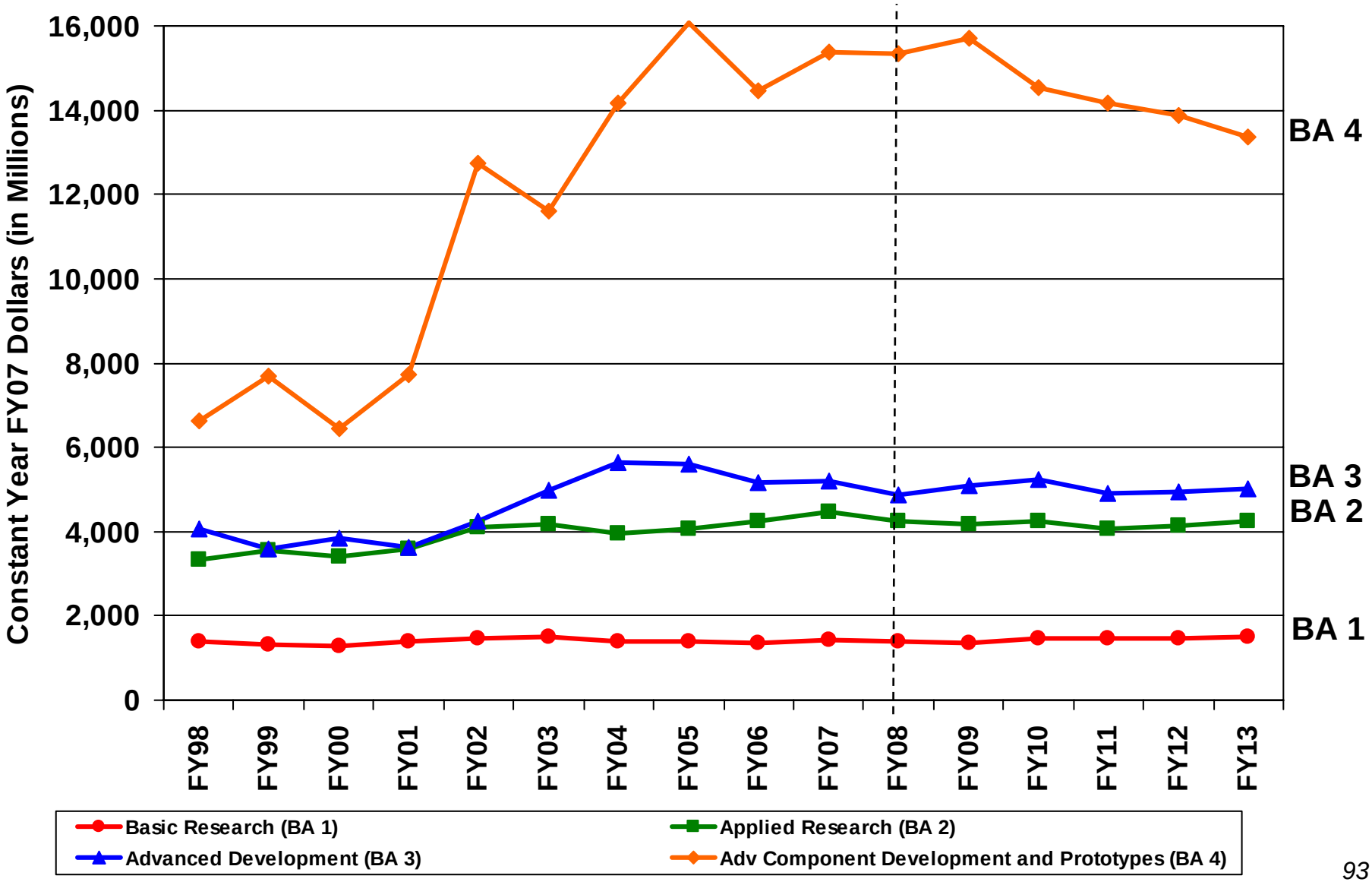
  Dr. Adam Russell and Ms. Bartlett Bulkley
  Scitor Corporation, 2006

- *The Global Technology Revolution 2020, In-Depth Analyses Bio/Nano/Materials/Information Trends, Drivers, Barriers, and Social Implications*

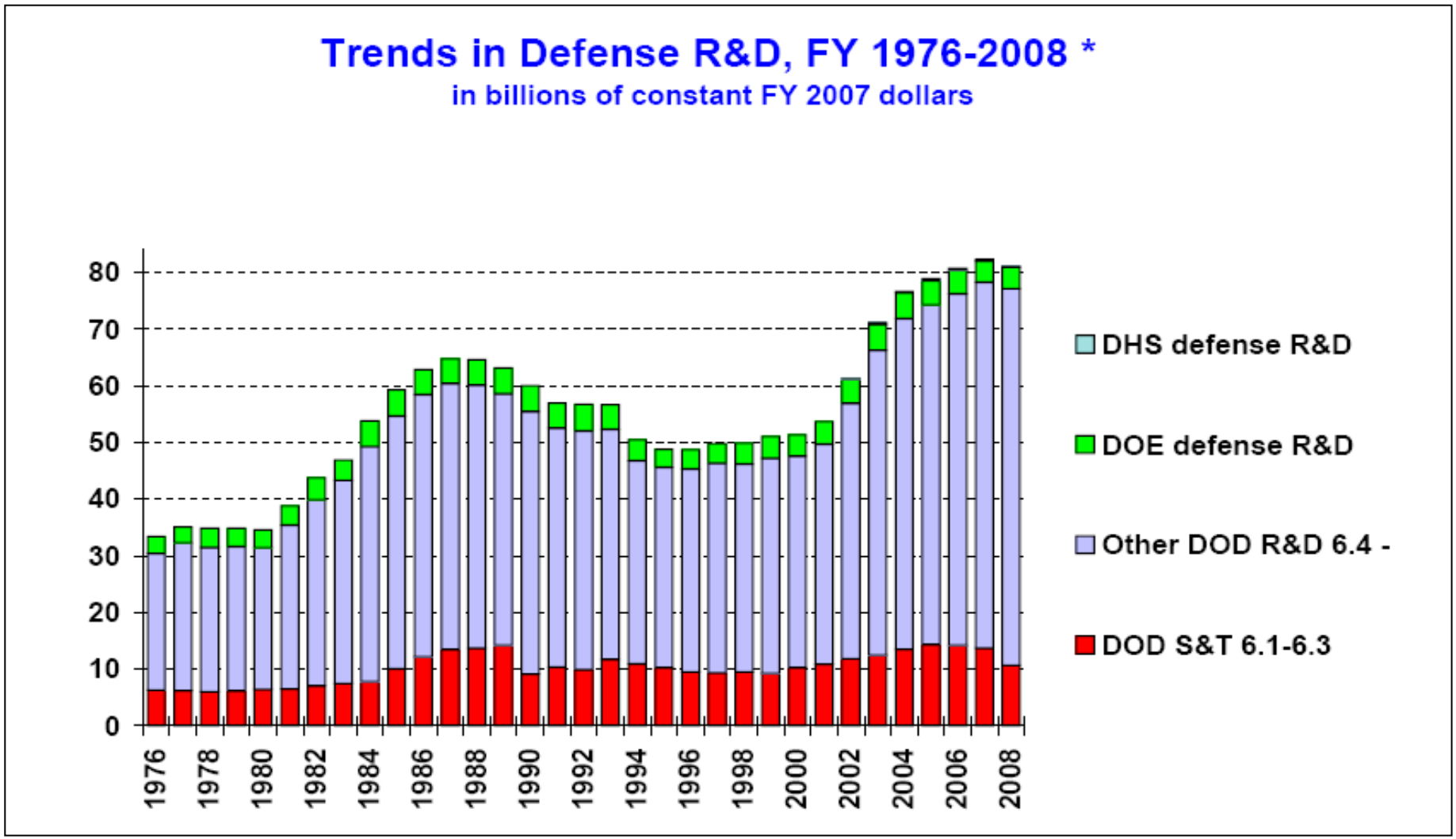
  Richard Silberglitt, Philip S. Antón, David R. Howell, Anny Wong
  RAND, 2006

DoD R&E Funding By Budget Activity

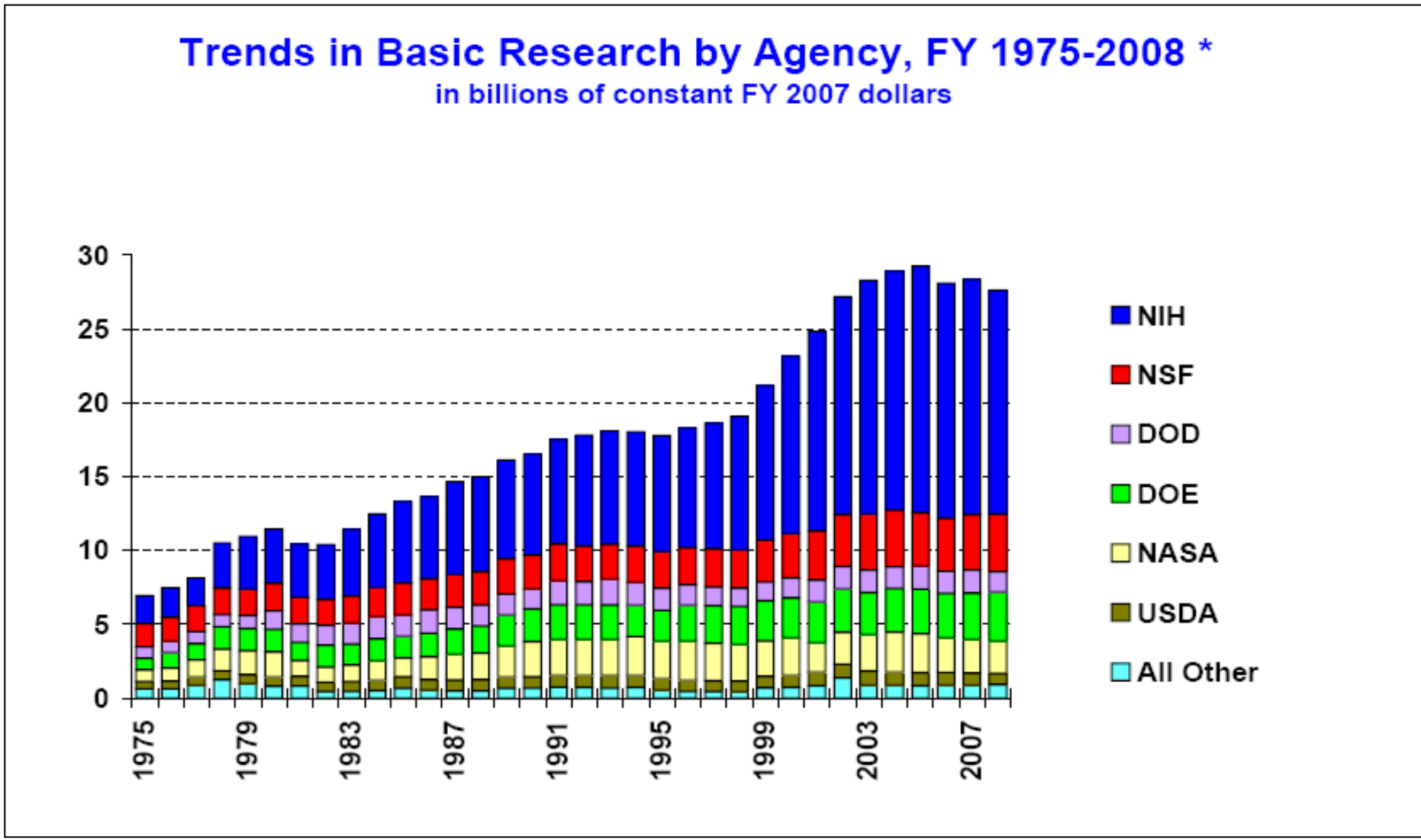
President's Budget Requests - in FY07 Constant Dollars



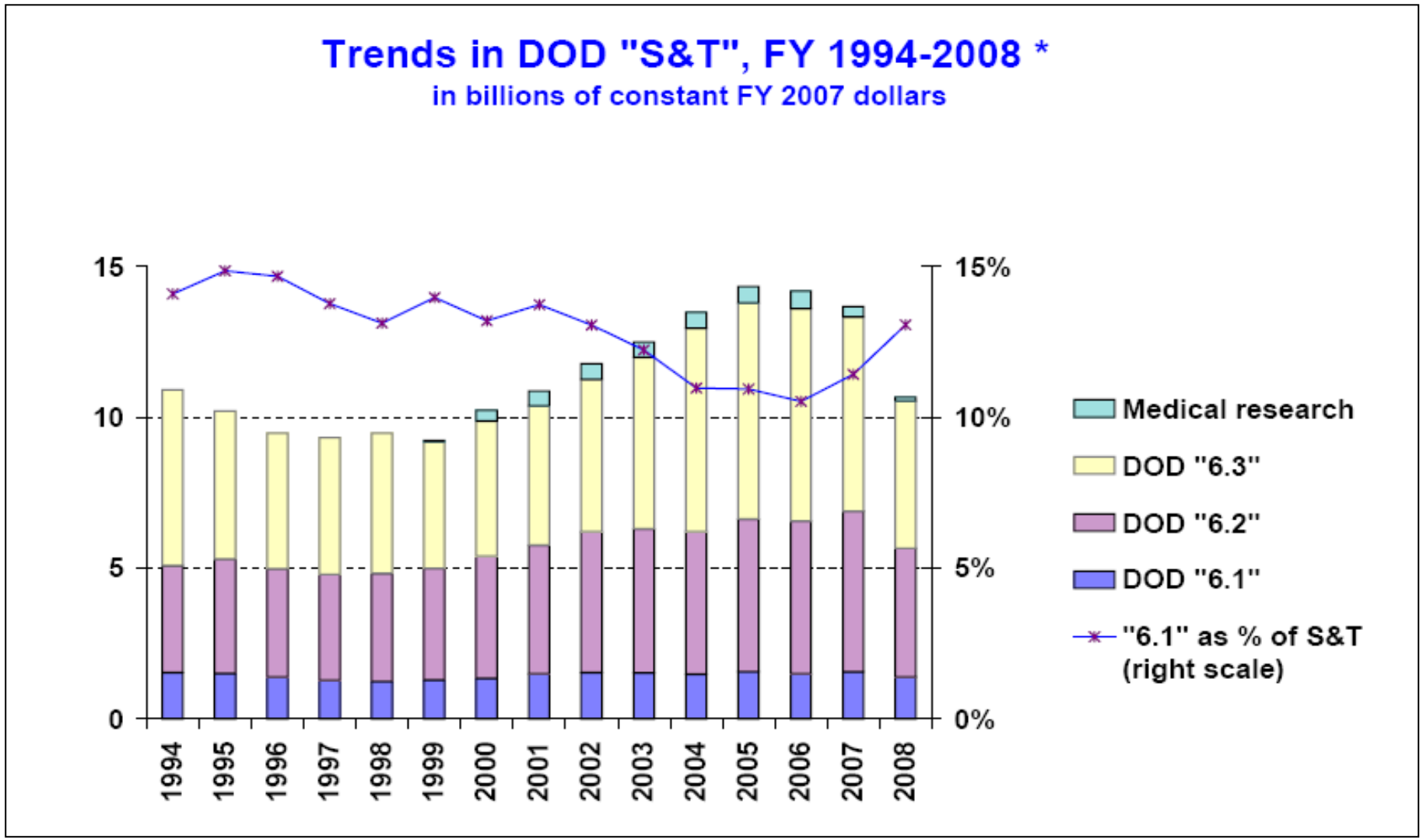
Defense R&D Spending



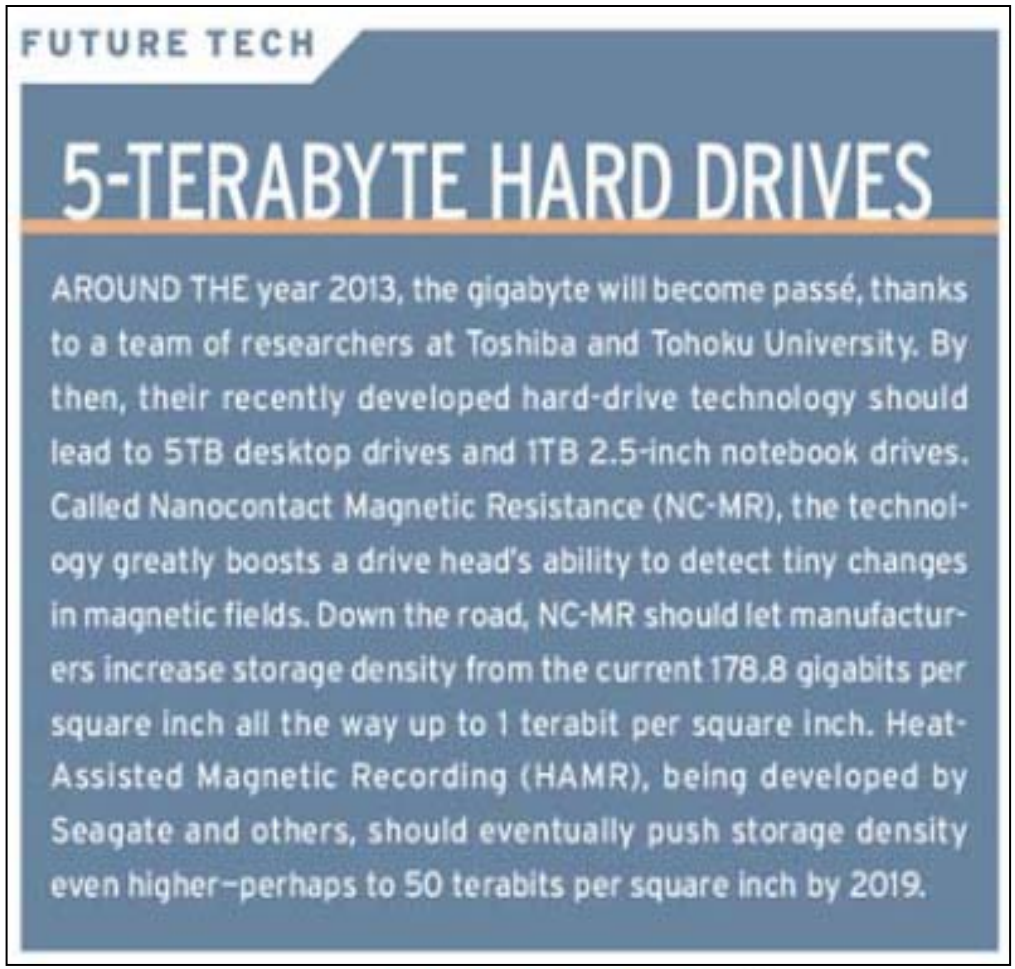
Federal Basic Research Spending



DOD S&T Spending



Moore's Law Continues



FUTURE TECH

5-TERABYTE HARD DRIVES

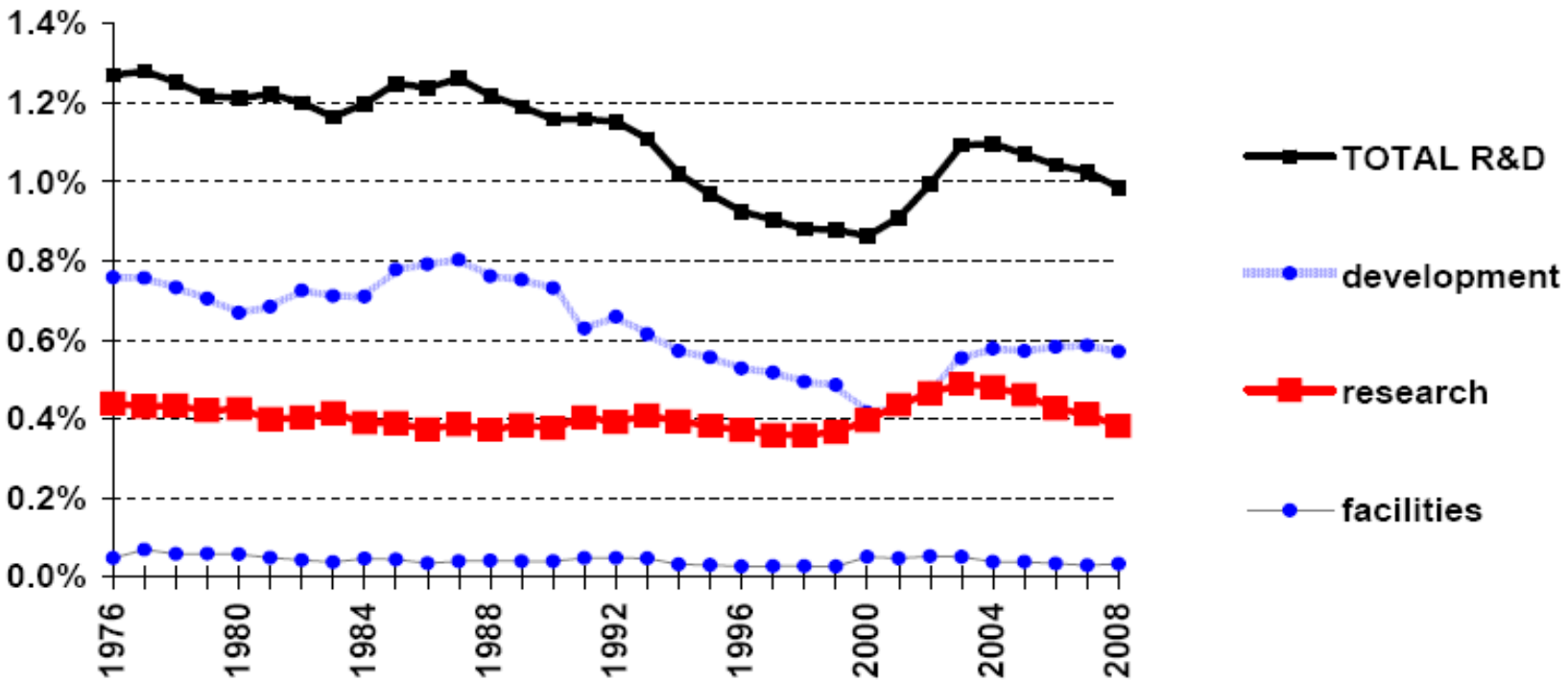
AROUND THE year 2013, the gigabyte will become passé, thanks to a team of researchers at Toshiba and Tohoku University. By then, their recently developed hard-drive technology should lead to 5TB desktop drives and 1TB 2.5-inch notebook drives. Called Nanocontact Magnetic Resistance (NC-MR), the technology greatly boosts a drive head's ability to detect tiny changes in magnetic fields. Down the road, NC-MR should let manufacturers increase storage density from the current 178.8 gigabits per square inch all the way up to 1 terabit per square inch. Heat-Assisted Magnetic Recording (HAMR), being developed by Seagate and others, should eventually push storage density even higher—perhaps to 50 terabits per square inch by 2019.

WWW.PCWORLD.COM / AUGUST 2007

45nm Size Comparison

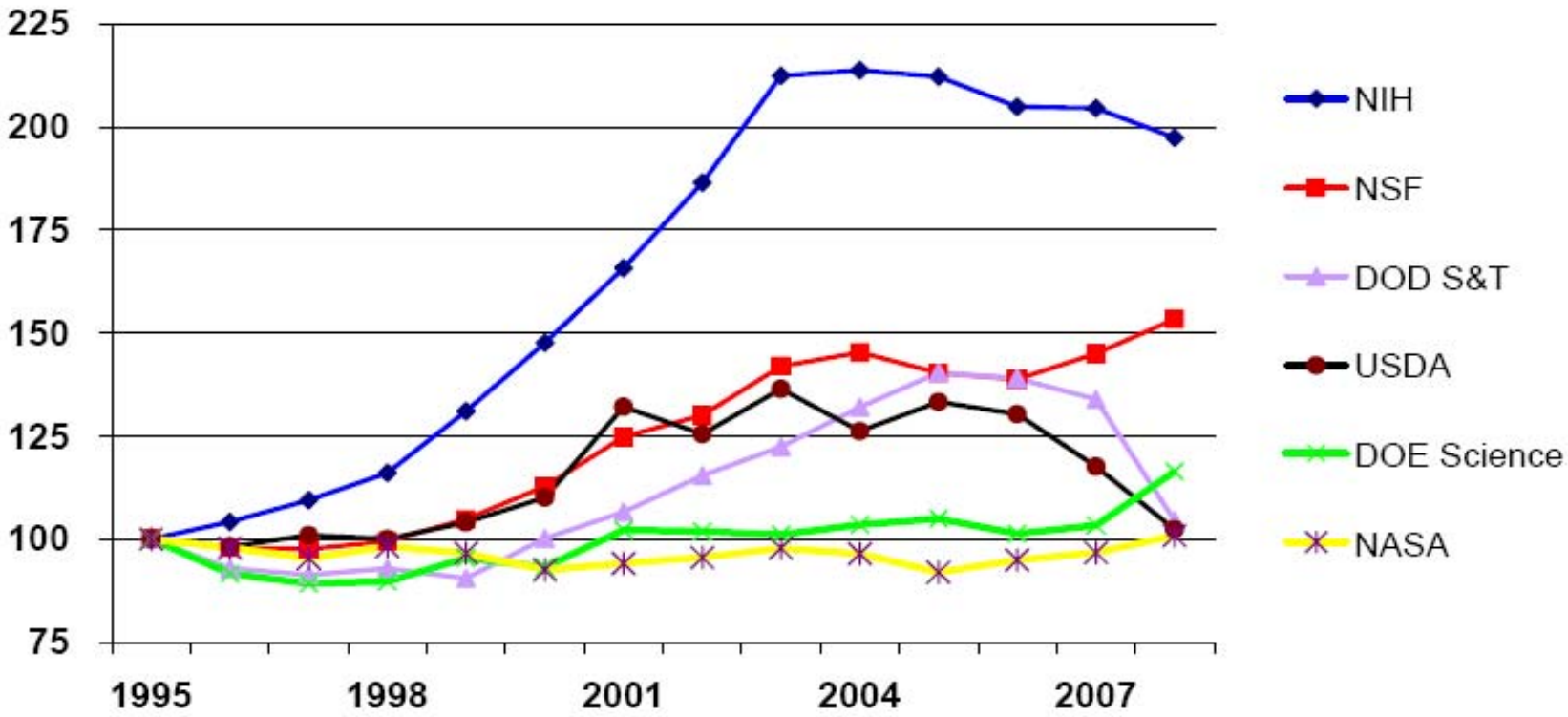
- A nail = 20 million nm
- A human hair = 90,000nm
- Ragweed pollen = 20,000nm
- Bacteria = 2,000nm
- Intel 45nm transistor = 45nm
- Rhinovirus = 20nm
- Silicon atom = 0.24nm

Federal R&D Spending



Trends in Federal R&D, FY 1995-2008*

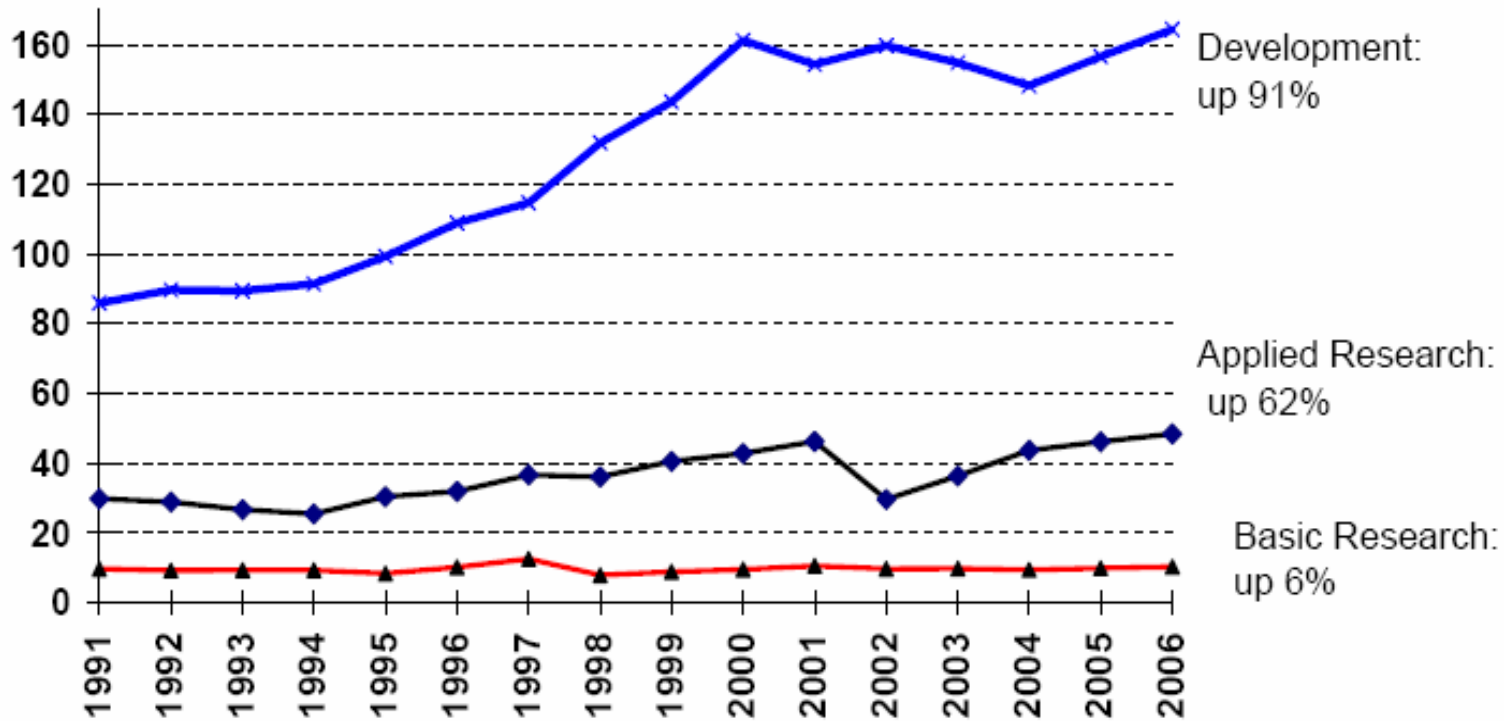
selected agencies in constant dollars, **FY 1995=100**



Industry R&D Trends

Trends in U.S. Industry R&D, 1991-2006

Expenditures in billions of constant 2006 dollars



Strategic Missile R&D Thrusts

- Science & Technology (BA 6.1-6.3)
- Radiation Hardened Electronics
- Technology for Sustainment of Strategic Systems
- Position, Navigation & Timing

- Thermal Protection Systems Materials & Structures
- Strategic Applications Programs (BA4 Air Force & Navy)
- Guidance
- Re-entry Vehicles
- Propulsion
- Command & Control

The need for technical intelligence . . .

manyworlds®

Converging Technologies for Improving Human Performance

EXECUTIVE SUMMARY

RISING ABOVE THE GATHERING

CLAYTON

National Bes

THE INNO DILE

The Revolutionary Book that Will Change the Way You Do Business

Terry C. Pierce

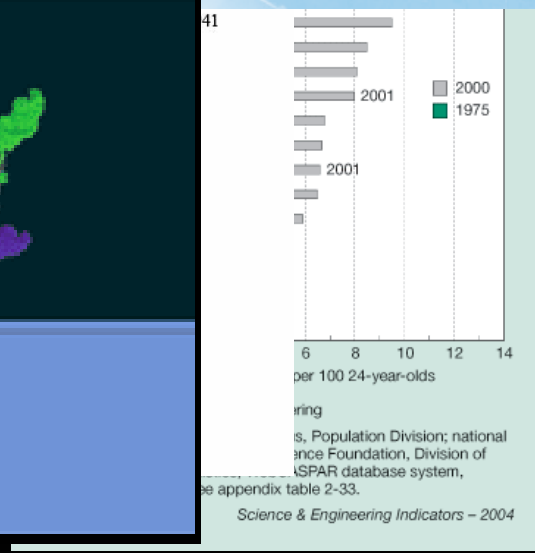
WARFIGHTING AND DISRUPTIVE TECHNOLOGIES

Disguising Innovation

MANAGING NANO-BIO-INFO-COGNO INNOVATIONS

CONVERGING TECHNOLOGIES IN SOCIETY

Springer



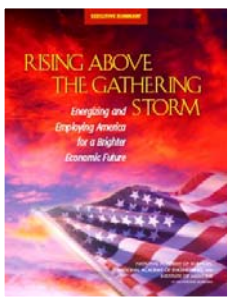
The Direction of Technical Intelligence

- **Other than WMD and terrorism, we see little strategic threat to US from today's forces, but:**
  - **Are we effectively projecting future foreign technology, capabilities, threats & emerging applications**
- **Possible threats to continued US military advantage are largely technology based, and rate of change of technology is increasing**
- **US maintains capability advantage unless:**
  - **New technology from adversary (e.g. stealth, PGM, NVDs)**
  - **Disruptive Technologies (radar, satellites, anti-satellite technologies)**
- **Therefore, must enhance technology intelligence to minimize surprise from**
  - **New technology from adversary**
  - **Technology/tactics that can mitigate our capability advantage**

Future Tech-Intel Motivation

"Move away from Lists of Lists"

- We need to understand global technology developments, evaluating their potential impact on national security
- Global development is so prolific that is difficult to keep up, much less address impact
- Limited funding, limited analysts, limited time prevent us from looking at everything
- Multiple analyses and lists of emerging tech exist, but most do not address impact to DoD or national security; those that do are typically generated by very small group with focused agendas
- Our concern remains "are we missing something" and "how do we better identify & track trends" because . . .



To avoid technology surprise we are moving to plan for an uncertain future, recognizing the global collaborative landscape by forecast future emerging technology & disruptive applicatons

Radiation Hardening Applications Program (RHAP)

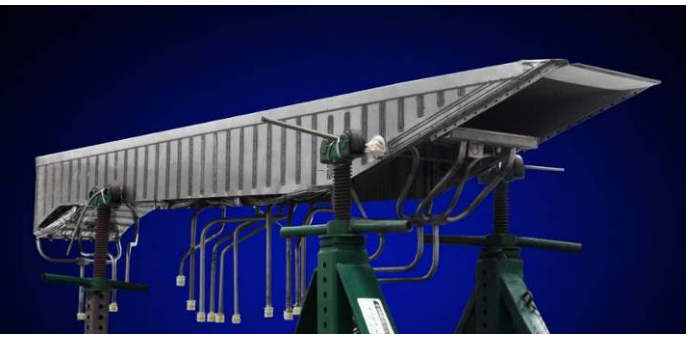
Objectives

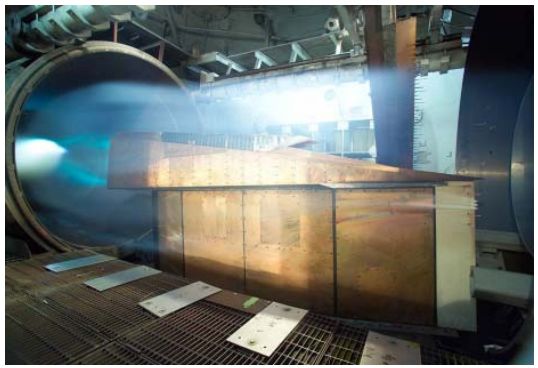
- **Develop a tool to model strategic system radiation effects**
  - **EMP missile plume coupling**
  - **Electrical parasitics noise coupling**
  - **Multi-wire cable SGEMP**
- **Develop a hardened boundary scan technology for mixed-signal integrated circuit application to improve testability**

Payoffs

- Improve the understanding of system survivability
- Improve the quality of radiation testing
- Cost savings to the program by reducing time in isolating failures
- Reduce assembly reworks by detecting / isolating analog faults
- Capture unique skills in RAD Hard system design

Air Force Hypersonic X-51 Scramjet Engine Demo (SED)





Description	Benefits to the War Fighter
Flight Demo HyTech HC Scramjet Engine • Fixed geometry scramjet, 12 min durability • Waverider airframe w/ ATACMS booster • Proves scramjet performance in flight	Near Term: Affordable Fast Reaction Standoff Weapon • Time sensitive targets: rapid response, long range standoff (600 NM in 10 min) • Deeply buried targets: terminal velocity 1K-4K fps • 250-500 lb modular payload (penetrator, explosive, or submunition) • Reduced vulnerability to enemy air defenses Far Term: Affordable On-demand Access to Space with Aircraft-like Operations
Technologies	
• Scramjet operating from Mach 4.5 to 7+ • Affordable, high lift-to-drag airframe • Storable endothermic hydrocarbon JP fuel	

Bottom Line: Warfighter Confidence

Right Materiel, Right Place,
Right Time, at the Right Cost -

All The Time

Planned Tasks Beginning in FY08

- **Enhanced Ballistic Reentry Vehicle**
  - **Future systems may require current ballistic RVs to fly at extended ranges**
  - **Identify current RV "weak links" for extended range ballistic flight**
  - **Design improvements for identified "weak links"**
  - **Current funding does not support flight testing**
- **Advanced Fuze Alternatives**
  - **Fielded fuzes utilize 1970's and 80's technology**
  - **Evaluate technologies for future fuze concepts**
  - **Reduce costs and increase maintainability while maintaining current capability and nuclear hardness**

Shift Happens . . .

We are currently preparing students for jobs and technologies that don't yet exist...in order to solve problems we don't even know are problems yet.

More than 70% of U.S. 4-year-olds have used a computer

There are students in China, Australia, Austria, Bangladesh, and the USA who

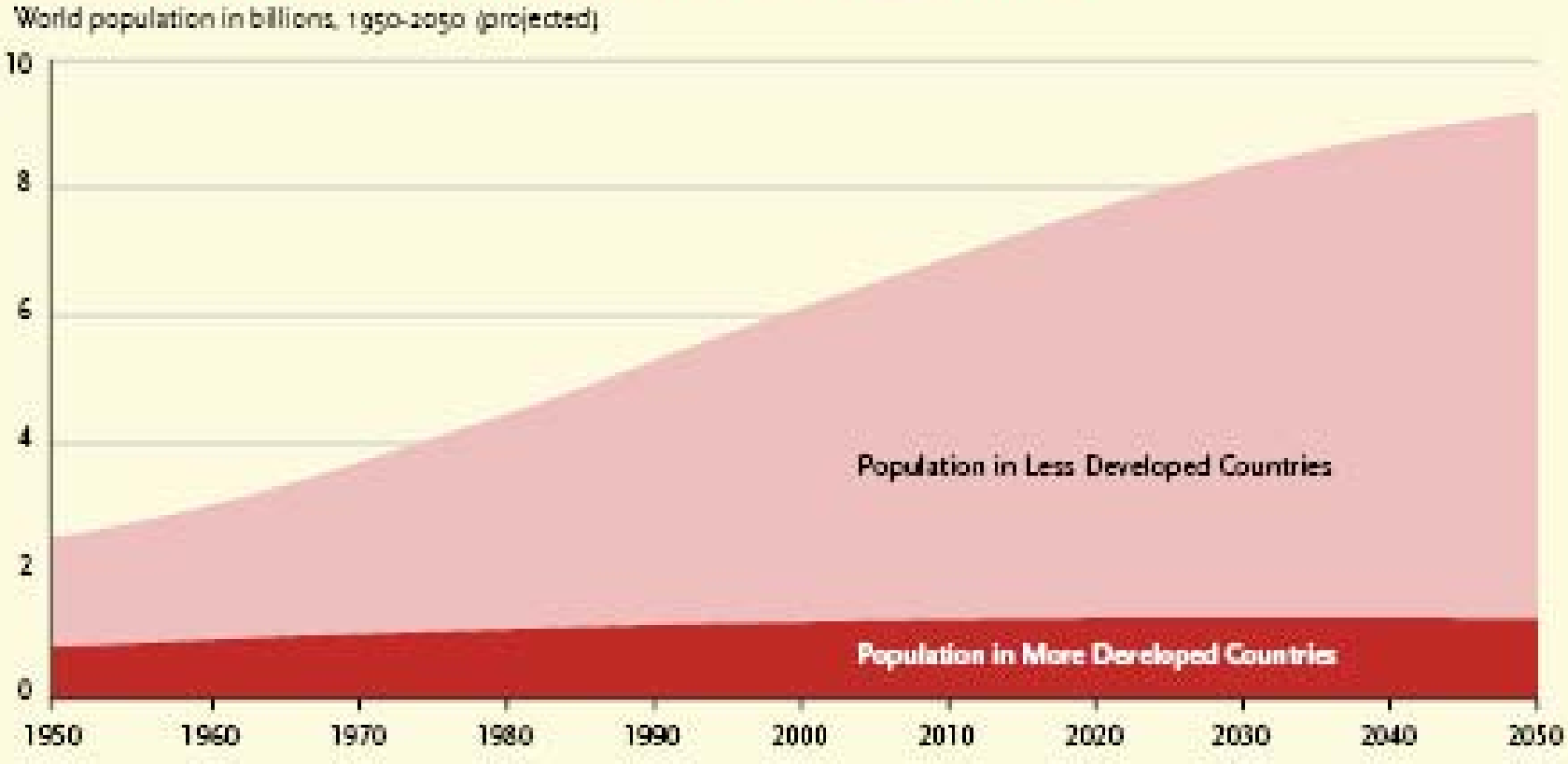
collaborate

on projects everyday

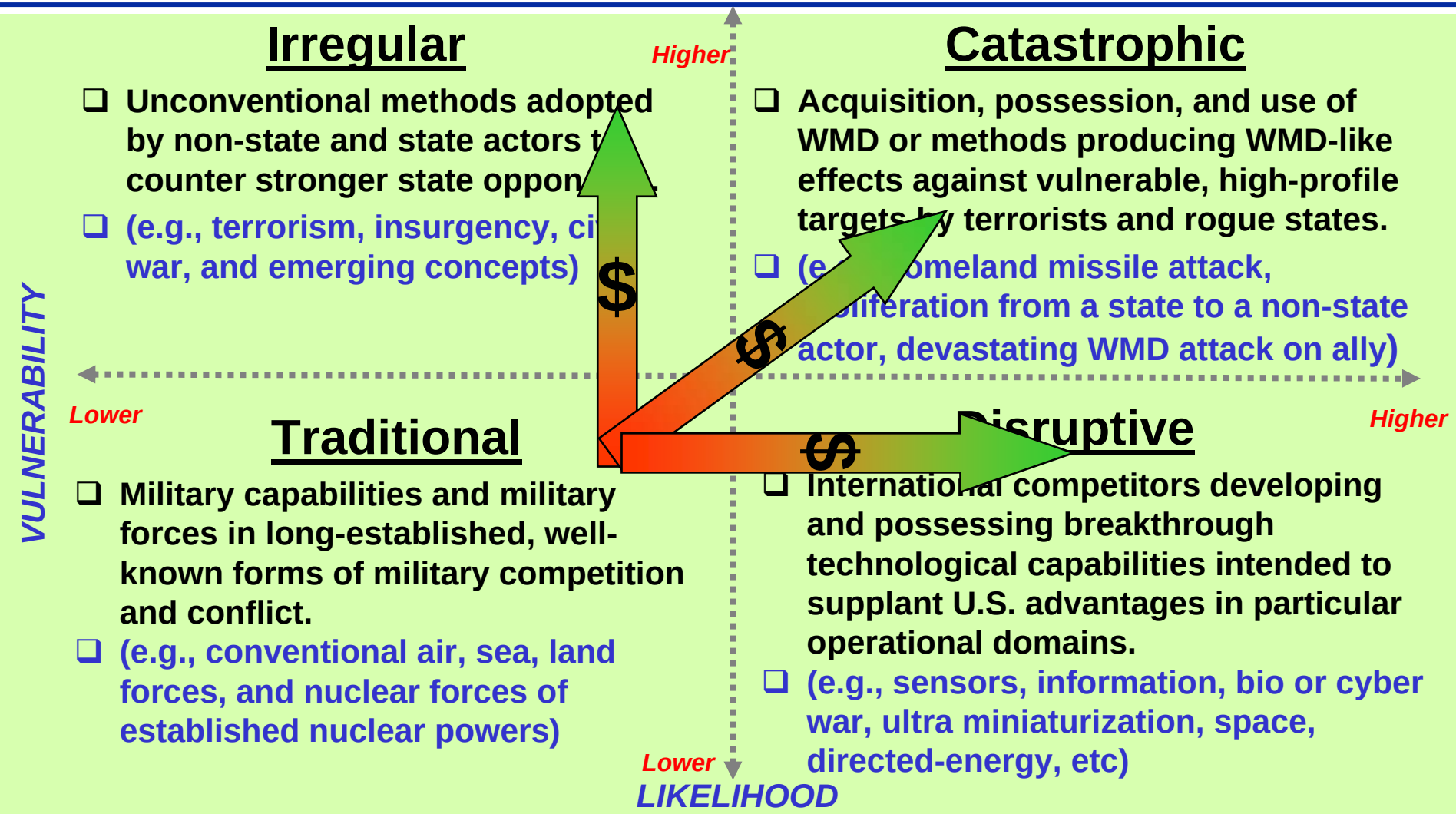
An Uncertain, Changed World

- **Technology Maturation Cycle**
- **Intellectual Capital Center Shifts**
- **Economic Factors Affecting R&D**

Population Trends



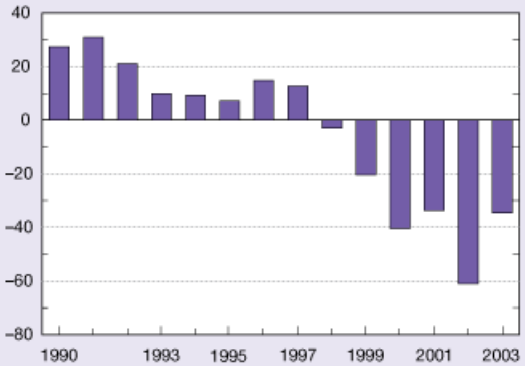
Changing Security Environment
Four Challenges



Uncertainty is the defining characteristic of today's strategic environment

More on the Trade Gap

Figure O-12
U.S. trade balance for five high-technology industries: 1990–2003

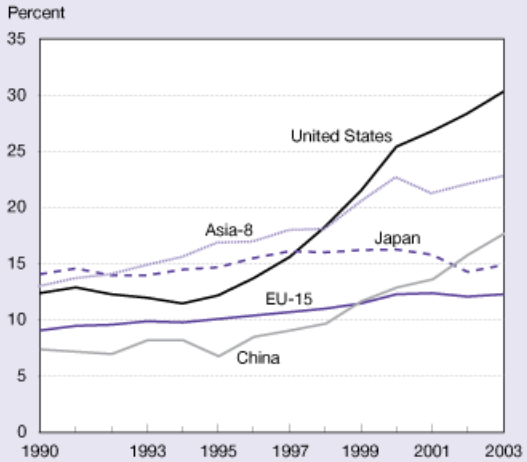


NOTE: Includes aerospace, pharmaceuticals, office and computing equipment, communications equipment, and scientific instruments.

SOURCES: Global Insight, Inc., World Industry Service database (2005). Historical data from United Nations Industrial Development Organization, United Nations System of National Accounts, Organisation for Economic Co-operation and Development; and country sources. See appendix table 6-4.

Science and Engineering Indicators 2006

Figure O-10
High-technology share of total manufacturing, by country/region: 1990–2003



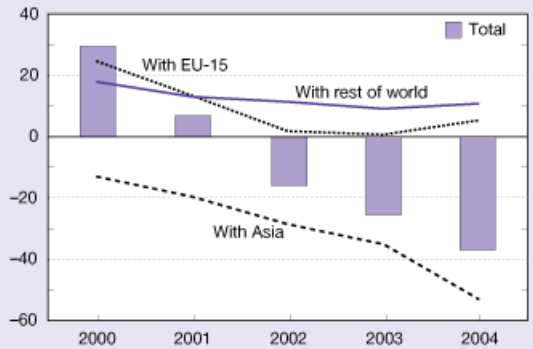
EU = European Union

NOTE: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand.

SOURCES: Global Insight, Inc., World Industry Service database (2005). Historical data from United Nations Industrial Development Organization, United Nations System of National Accounts, Organisation for Economic Co-operation and Development, and country sources. See appendix table 6-2.

Science and Engineering Indicators 2006

Figure O-13
U.S. trade balance in high-technology goods: 2000–04



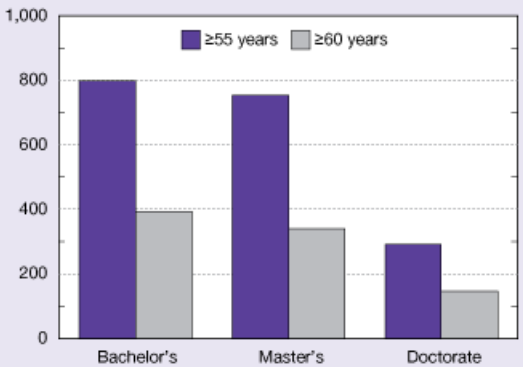
EU = European Union

SOURCE: U.S. Census Bureau, Foreign Trade Division, special tabulations (March 2005). See appendix table 6-6.

Science and Engineering Indicators 2006

More on Education

Figure O-35
Individuals in U.S. S&E labor force nearing retirement age, by degree level: 2003

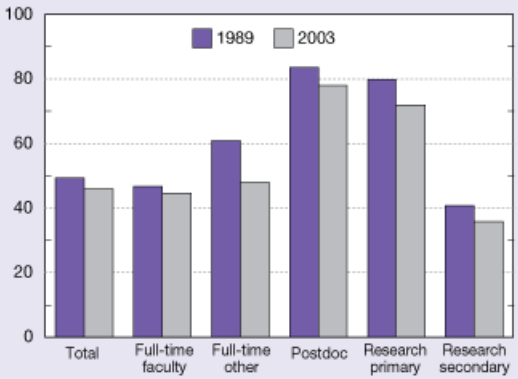


NOTE: Preliminary estimates made in 2005 based on 2003 data

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Survey of College Graduates, preliminary estimates (2005).

Science and Engineering Indicators 2006

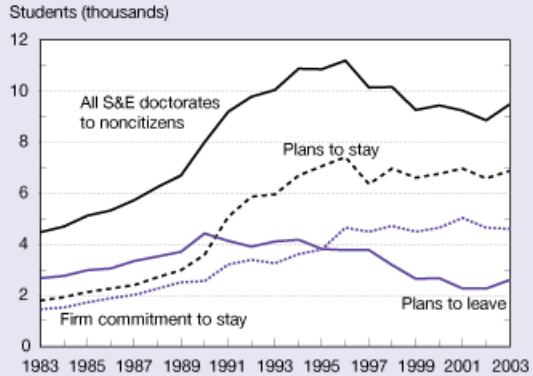
Figure O-43
Academic S&E doctorate holders receiving federal support for research: 1989 and 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-37.

Science and Engineering Indicators 2006

Figure O-31
Foreign student plans to stay in United States after receipt of U.S. S&E doctorate: 1983–2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2005). See appendix table 2-33.

Science and Engineering Indicators 2006

Capabilities to Defeat Terrorist Networks

- Persistent surveillance
- Locate, tag, and track terrorists in denied areas
- Capabilities to fuse intelligence
- Language and cultural awareness
- Non-lethal capabilities
- Joint coordination, processes and systems

Non-kinetic capabilities

- Urban warfare capabilities
- Prompt global strike
- Riverine warfare capabilities

Kinetic Capabilities

All These Capabilities are Joint, Coalition Centric

Capabilities to Defend the Homeland In Depth

- Interoperable, joint command and control
- Enhanced air and maritime awareness
- Consequence management
- Broad spectrum medical countermeasures

Non-kinetic capabilities

All These Capabilities are Joint, Coalition Centric

Capabilities to Prevent the use of Weapons of Mass Destruction

- Locate, tag, track, and characterize
- Stand off fissile material detection
- Wide area persistent surveillance
- Capabilities to “render safe” WMD
- Non-lethal weapons

} ***Non-kinetic capabilities***

All These Capabilities are Joint, Coalition Centric

Capabilities to Shape the Choices of Countries at Strategic Crossroads

- Improved language and cultural awareness
- Persistent surveillance (penetrate and loiter)
- Cyberspace shaping / defense
- Secure broadband communications
- Integrated defense against all missiles

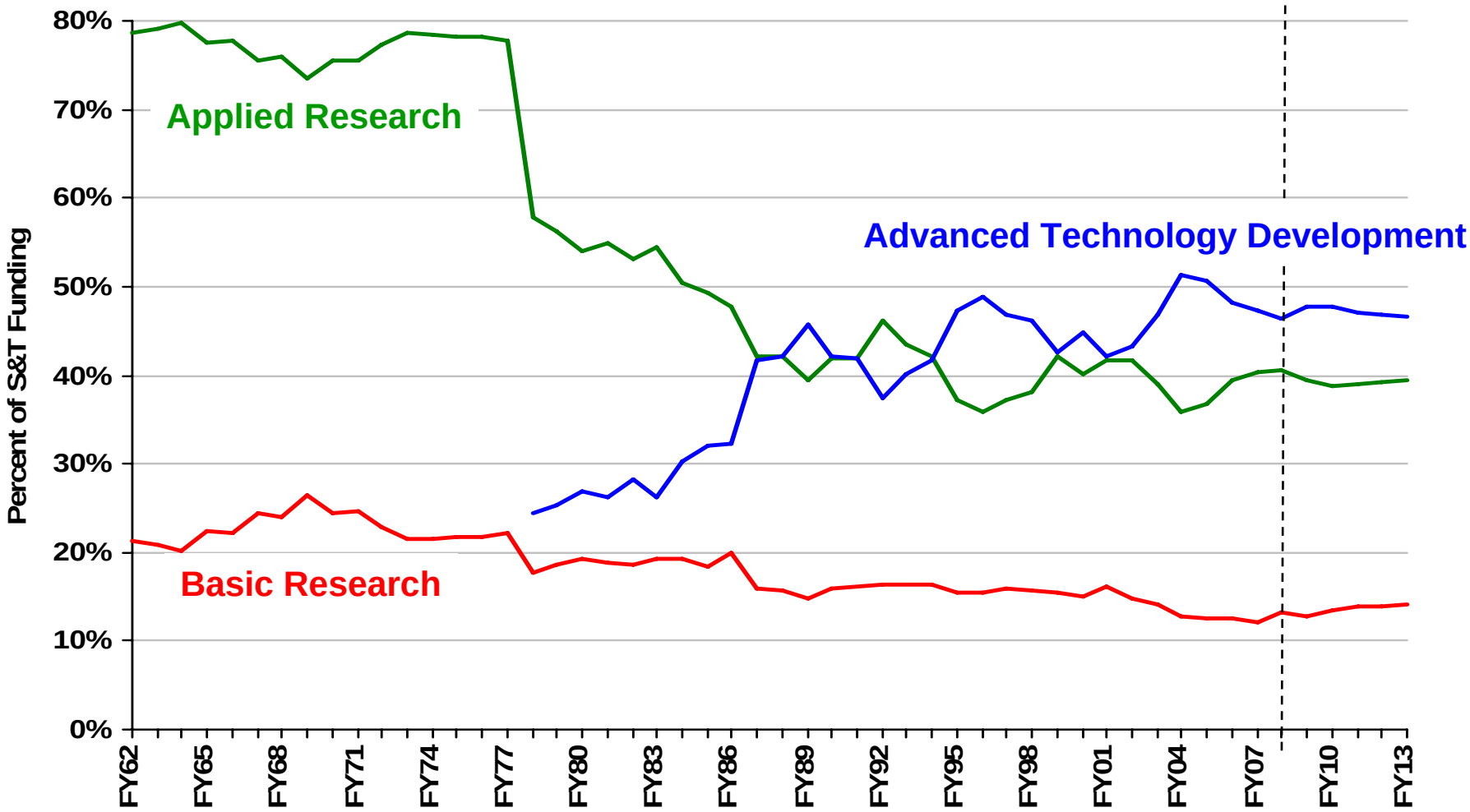
Non-kinetic capabilites

- **Prompt, high-value global strike**
- **Air dominance**
- **Undersea stealth**

Kinetic

Most of These Capabilities are Joint, Coalition Centric

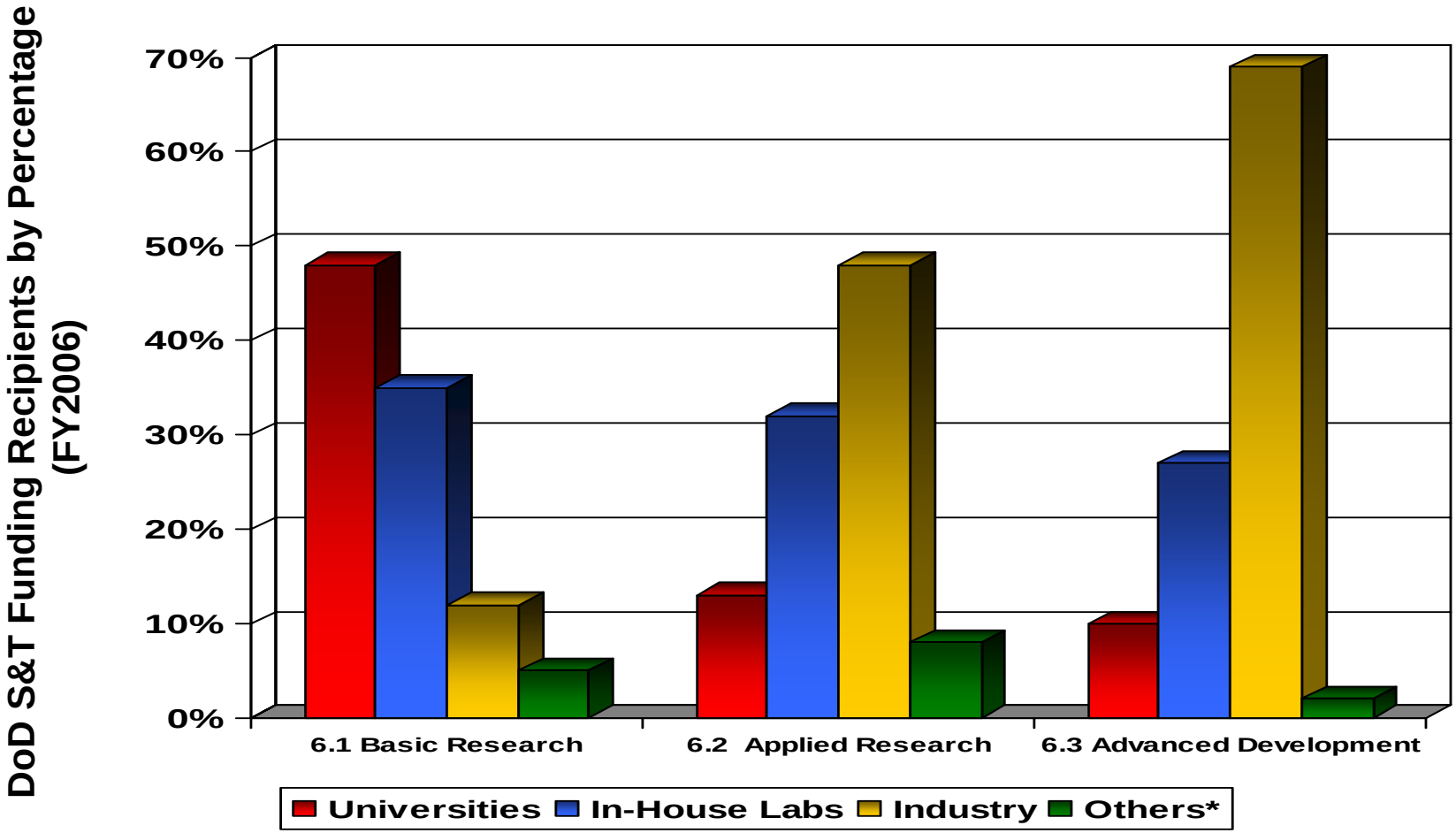
DoD S&T Requests
- by Percent Budget Activity -



DoD is increasing emphasis on nearer-term projects

** ***Note:*** Advanced Technology Development funding began in FY78

Recipients of DoD S&T Funds



***Includes non-profit institutions, State & local govt., & foreign institutions**

Source: National Science Foundation Report (FY 2006)

Technology for Sustainment of Strategic Systems (TSSS)

DoD Science and Technology Program Initiated by USD(AT&L)
in response to the highest priority needs identified by USSTRATCOM

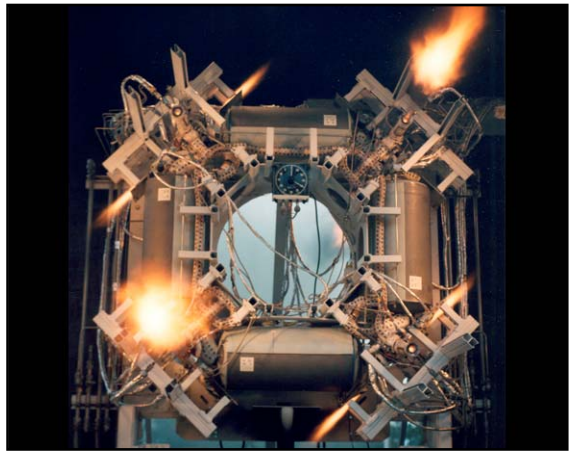
Missile Propulsion
Post-Boost Control System Propulsion, Valve Technology & Materials
Ageing and Surveillance
Missile Flight Sciences
Missile Electronics
Underwater Launch
Guidance Navigation and Control for Strategic and Precision Strike
Ordnance Initiation Technology for Strategic Missile Systems
Submarine Navigation

TSSS supports the capability to sustain and upgrade existing Inter-Continental Ballistic Missiles (ICBM) and Fleet Ballistic Missiles (FBM) systems and to engineer, design, and develop new ballistic missile systems. Contributing factors include maintaining system safety, reducing operations and maintenance (O&M) costs, increasing service life of existing systems, and reducing reliance on physical testing of existing strategic systems.

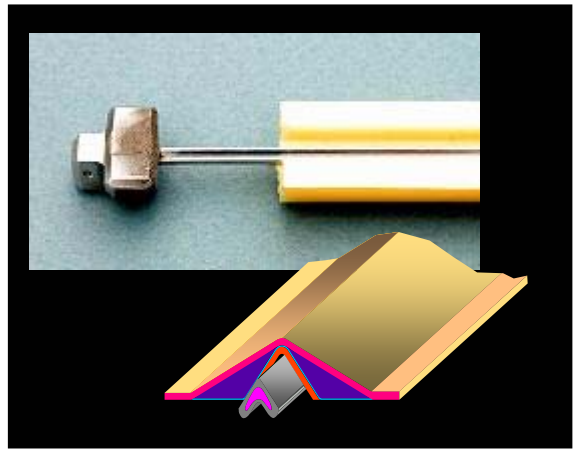
TSSS Technology Objectives

Missile Propulsion

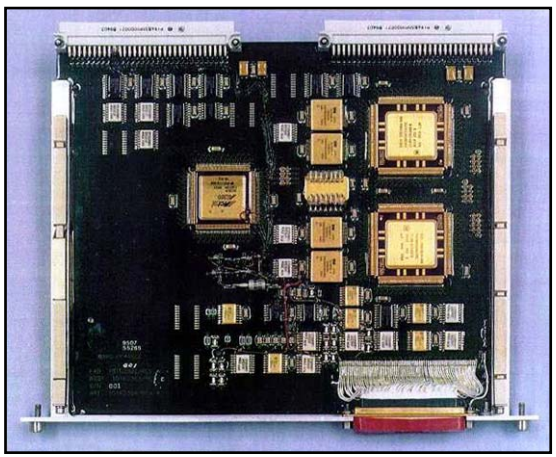
Post Boost Control



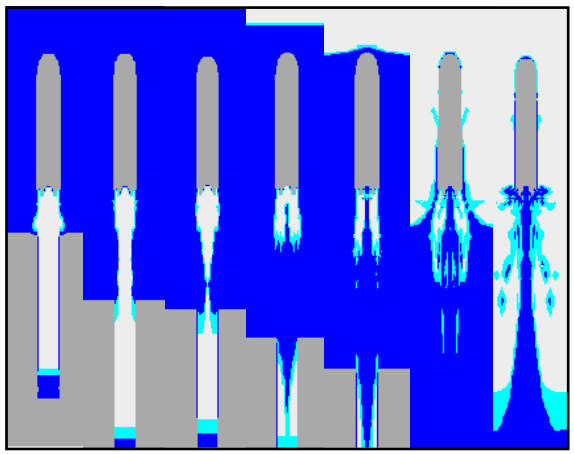
Ordnance



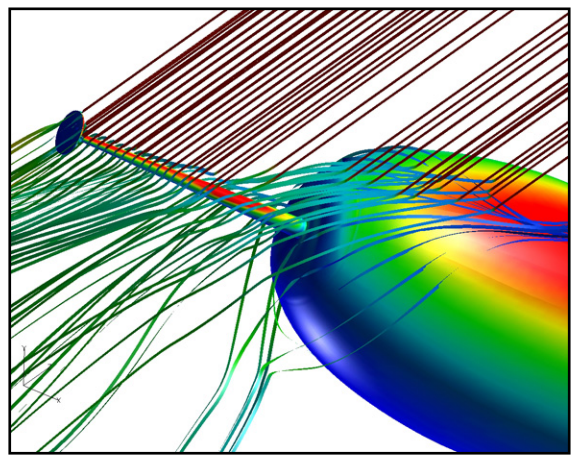
Missile Electronics



Underwater Launch



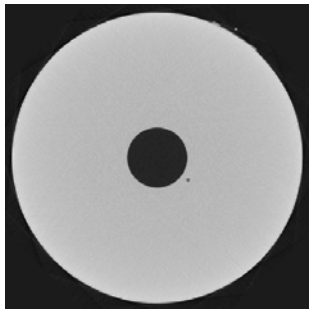
Flight Sciences & Analysis



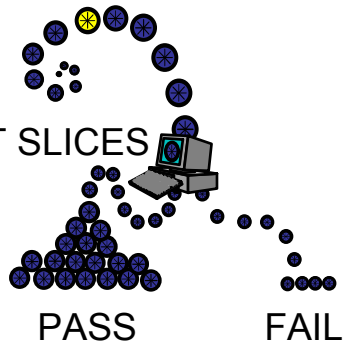
TSSS - Aging and Surveillance

NDE Data Processing Program

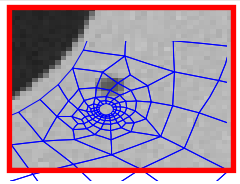
CT Flaw Detection



Automated Flaw Evaluation

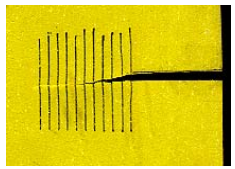


Critical Defect Assessment Program

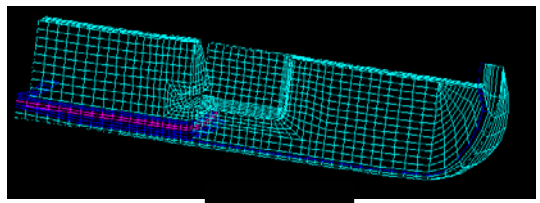


Automated Flaw Meshing

Automated Fracture Propagation



3D Structural/Ballistic Modeling

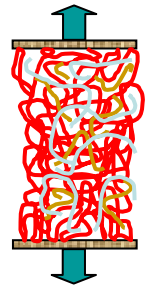


Service Life Prediction

Service Life Prediction Technology Program

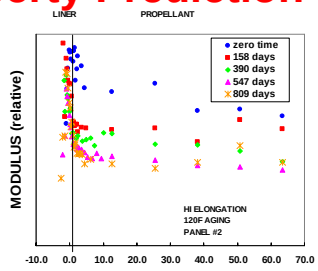
Chemical/Mechanical Property Assessment

Polymer Mechanics



Particle Packing

Chemical/Mechanical Property Prediction



Strategic Propulsion Applications Program (SPAP)

Objectives

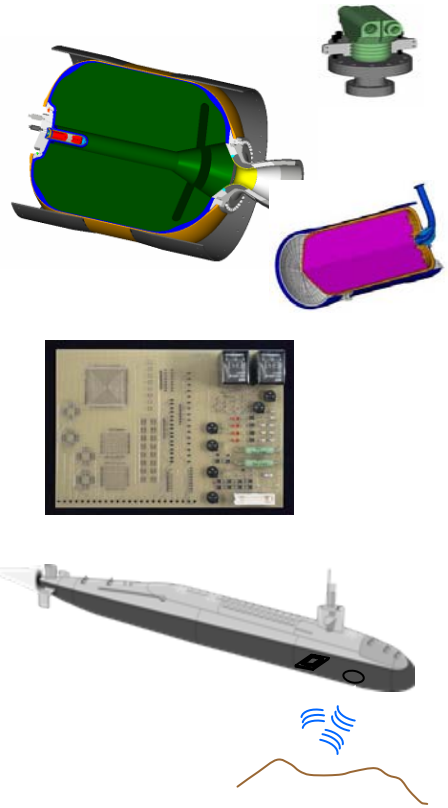
- Demonstrate/validate emerging technologies suitable for ICBM/SLBM
- Maintain critical skills and tools
- Improve predictive aging models/techniques
- Demonstrate Systems Engineering Skills for systems and subsystems integration
- Reduce development/qualification time required to initiate production of alternative components

Payoffs

- Viable alternative technologies in support of D5 Life Extension
- Demonstrations of affordable and high performance technologies for boost motor, PBCS and ordnance
- Maintenance of SLBM-unique development and sustainment skills related to high-energy, high-elongation Class 1.1 Propellant
- Elimination of hazardous materials in Ordnance

Strategic Missile System Technology Efforts (ICBM and SLBM)

- Technology for the Sustainment of Strategic Systems (TSSS)
  - Propulsion (IHPRPT)
    - Missile Boost Propulsion
    - Post Boost Control System Propulsion
    - Aging and Surveillance – Life Prediction, NDE
  - Guidance Navigation and Control
  - Navigation Sonar
  - Ordnance
  - Electronics
  - Systems Engineering Tools



Emphasizes Technology Sustainment
(Reduced Cost of Ownership, Increased Performance)

Guidance Applications Program (GAP)

Objectives

- **Provide a minimum strategic guidance technology design and development capability**
- **Transition to a long-term readiness status to support deployed systems**
- **Focus on modern replacement alternatives to antiquated or obsolete technologies which provide radiation hardened velocity, attitude (gyro) and stellar sensing capabilities with strategic performance**

Payoffs

- Preserves critical design and core development capability
- Allows for orderly replacement of unsupportable technologies
- Applications to alternate missions
- Lower life cycle costs

QDR Priority Formulation

- **Balanced what the US wants to protect against (Strategic Challenges) and outcomes the US wishes to accomplish (Strategic Outcomes)**
  - **Strategic Challenges**
    - **Traditional**
    - **Irregular Warfare**
    - **Combating WMD**
    - **Disruptive**
  - **Strategic Outcomes**
    - **Defeat Terrorist Networks**
    - **Defend the Homeland in-Depth**
    - **Shape Choices of Countries at Strategic Crossroads**
    - **Prevent the Use of WMD**

QDR In A Banner – A Shift in Emphasis from "Kinetic" to "Non-Kinetic" Systems

Technology and the Modern World

" We can't solve problems by using the same kind of thinking we used when we created them"

Albert Einstein

There is no reason anyone would want a computer in their home
Ken Olson, President, DEC, 1977

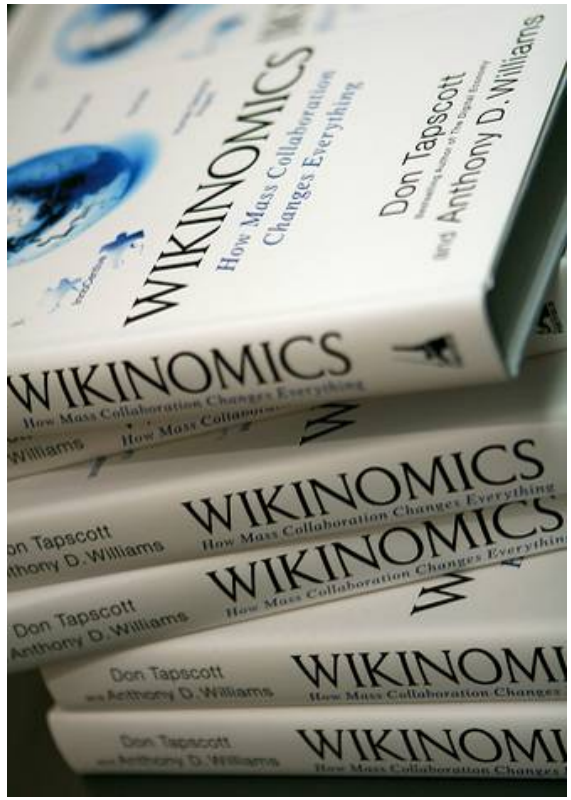
Everything that can be invented has been invented
Charles Duell, Commissioner US Patent Office,1899

"I think there is a world market for maybe five computers."
Thomas Watson, IBM Chairman, 1943

"640K ought to be enough for anybody."
Bill Gates, CEO of Microsoft, 1981

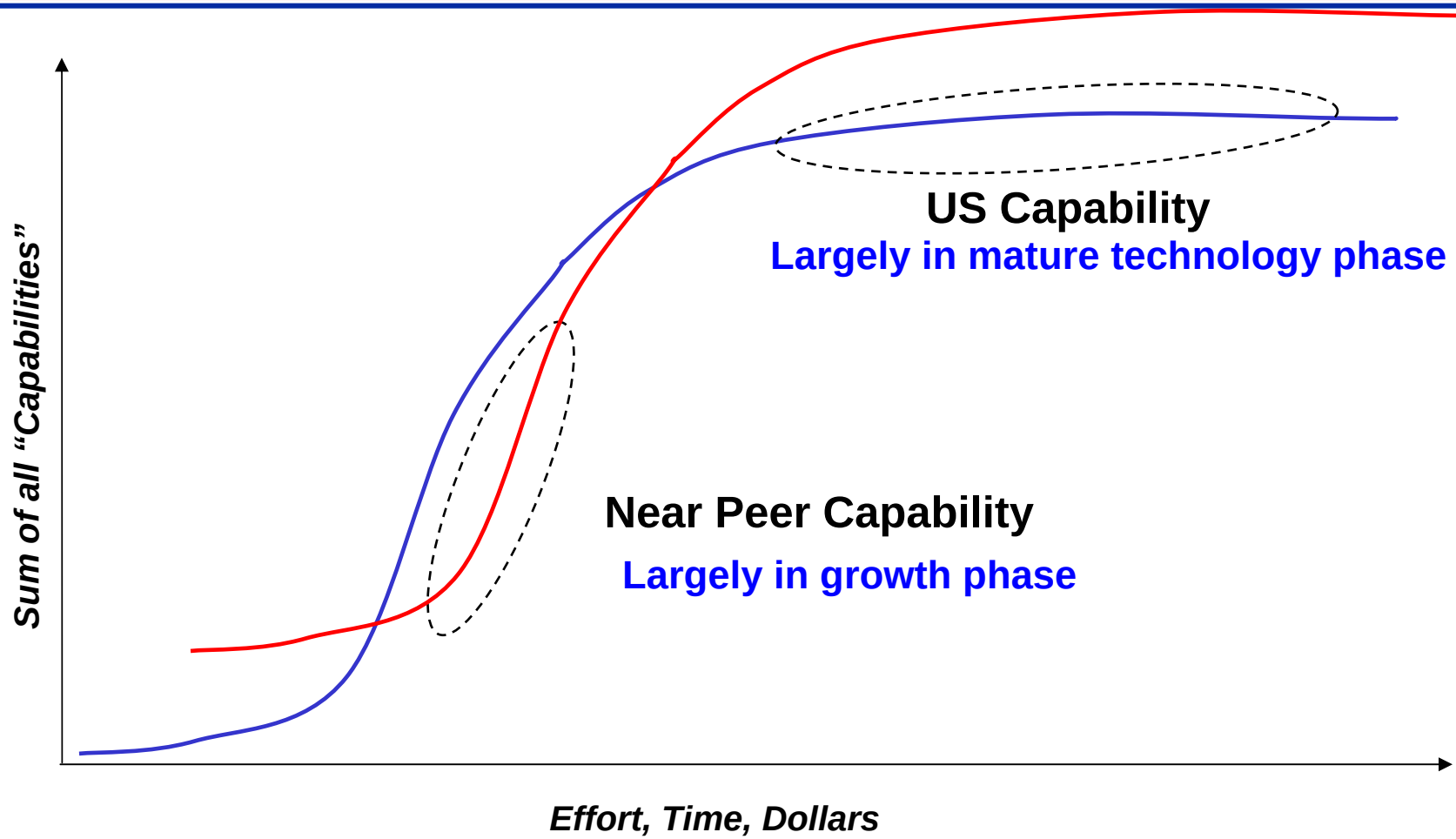
If you don't know where you are going, you might end up someplace else
Yogi Berra

These changes, among others, are ushering us toward a world where knowledge, power and productive capability will be more dispersed than at any time in our history – a world where value creation will be fast, fluid, and persistently disruptive.
Don Tapscott and Anthony Williams, Wikinomics



"The conjunction of 21st century internet speed and 12th century fanaticism has turned our world into a tinderbox" -- Tina Brown ,Washington Post, 19 May 2005

What Can Happen if We Hold onto Mature Technology Too Long



ASSERTION: Without changing the US investment profile, US could spend more yet have capability gap close

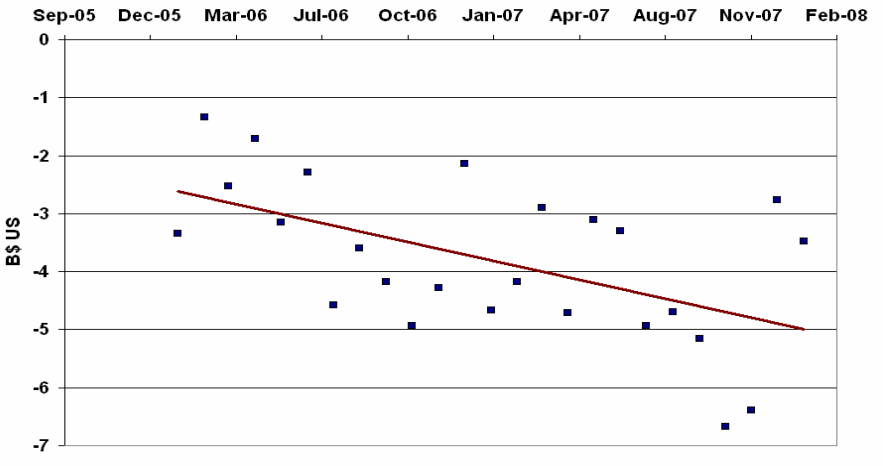
Technological "Shock" of Desert Storm

- Based on dominant US capabilities "in the commons"
  - Low observability
  - Spaced-based capabilities
    - Comms
    - GPS
  - Night Vision
  - Info Ops
  - Missile Defense

Mega-Trends Economy

The US Trade Balance

US Advanced Technology Products Trade Balance



Source: The Economist, Jan 24, 2008

- US Merchandise Trade Balance for 12 Months ending December 2007: 815.6B$
- Largest Advancing Technology deficits in these areas (2007YTD)
  - Information technology -7.9B
  - Life Sciences -1.7B
  - Opto-electronics -1.5B
  - Advanced Materials -0.8B
- Losses Outpaced gains in:
  - Aerospace +4.0B
  - Electronics +1.9B
  - Biotechnology +0.3B

Source: The Economist, March. 8, 2008

Source (FT900: U.S. International Trade in Goods and Services, Released January 2008, US Cencus Bureau), Data not Seasonally Adjusted
http://www.census.gov/foreign-trade/Press-Release/current_press_release/press.html

Disruptive Technologies

Frequently Take a Forcing Function

Technology	Approximate Date Of First Lab Demo		Approximate Date of First Military Apps	Technology
Radio	1901	*World War I*	1914	Electronics
Airplane	1903		1916	Internal Comb
Vacuum Tube	1906		1915	Electronics
Mechanized Tank	1916		1916	Engine/Metals
Liquid-Fueled Rockets	1922	*World War II*	1944	Chem/Metals
Radar	1925		1939	Electronics
Gas Turbine	1935		1944	Metals
Digital Computer	1943		1945	Electronics
Ballistic Missile	1944		1945	Chem/Guide
Nuclear Weapons	1945		1945	Physics
Transistor	1948	*Cold War*	1957	Electronics
Inertial Navigation	1950		1955	Electronics
Nuclear Propulsion	1950		1954	Physics
Artificial Earth Satellites	1957		1960	Computers
Integrated Circuit	1960		1970	Electronics
Laser	1961		1967	Photonics
Precision Weapons	1965		1967	Electronics

One function of S&T – Keep the pantry stocked

Disruptive Technology
A Case Study

- Digital Equipment Corporation:
  - 1957 -- Founded
  - 1960 -- Programmable Data Processor 1 (PDP-1) Introduced
    - World's First Minicomputer
    - 10% cost of Mainframe Computers
  - 1965 -- PDP-8 Rolled-out; World's #1 Selling Computer
  - 1970's – 1990—DEC #2 International Computer Sales
  - 1990 -- 120,000 Employees; Revenues $14B
  - 1998 – Company Bought by Compaq—and Dead

"It was the sudden demise of DEC that first drew my attention. How could a company, once described by Business Week as a freight train that obliterates all competitors, fall so precipitously?" Interview with Clayton Christensen, Harvard Business School on Line, April 1999