



Department of Defense S&T In a Changing Landscape

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Principal Deputy
Defense Research and Engineering
5 September 2008***

Technology and the Modern World



THE BLACK SWAN



The Impact of the
HIGHLY IMPROBABLE

Nassim Nicholas Taleb

“ 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

Director of Defense Research & Engineering Vision



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



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

***Any Adversary includes
both State and non-State
actors***



DoD S&T Has Developed Technologies That Changed Warfighting



- Disruptive technologies resulting from technology push:

- Internet
- GPS
- Night vision
- Lasers
- Stealth
- Predator
- Global Hawk

All provided dominant capability

- None of these emerged from requirements



Stealth

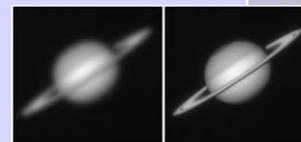


UAVs



GPS

Advanced Optics and Lasers



Night Vision



Yesterday's Investment in S&T Provided Today's Capability Advantage

Desert Storm



- **US dominance over Soviet-era systems “shocked” potential adversaries and combined to give US conventional superiority**
 - Precision Weapons
 - Night Vision
 - Low Observability
 - Networked Systems
 - Space-Enabled Capabilities
- **The advent of information-based warfare feeding the emergence of irregular warfare**





An information age Sputnik?

NO....but this guy is far cry from a massed country

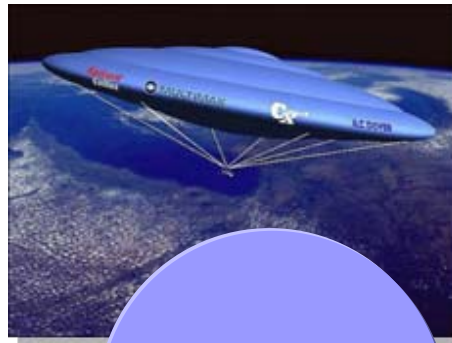


George Hotz, 17, of Glen Rock, New Jersey holding the iPhone® that he separated from the AT&T network and used on the T-Mobile Network. **Career goal: hack the human brain**

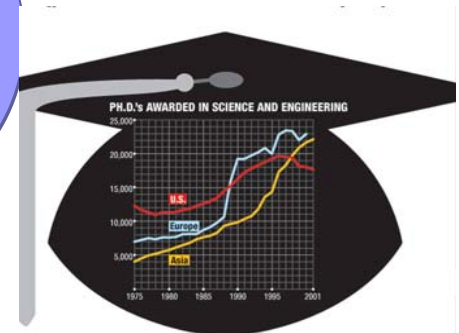
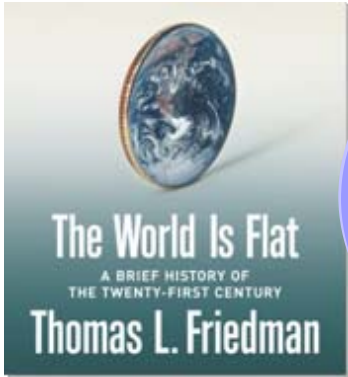
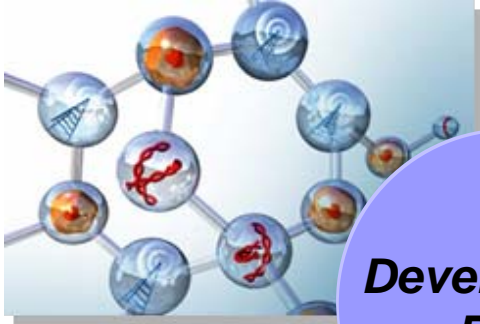
- ❑ Apple and AT&T released the iPhone on 29 June
- ❑ An exclusive agreement guaranteed the iPhone could only be used on AT&T's mobile network
- ❑ Hotz spent approximately 500 hours working on his “summer project”
- ❑ The hack was announced on 24 August.
 - ❑ AT&T - market cap: \$245B
 - annual revenue: \$90B
 - ❑ Apple - market cap: \$117B
 - annual revenue: \$23B
 - ❑ Hotz - PRICELESS

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

A Changing World . . .



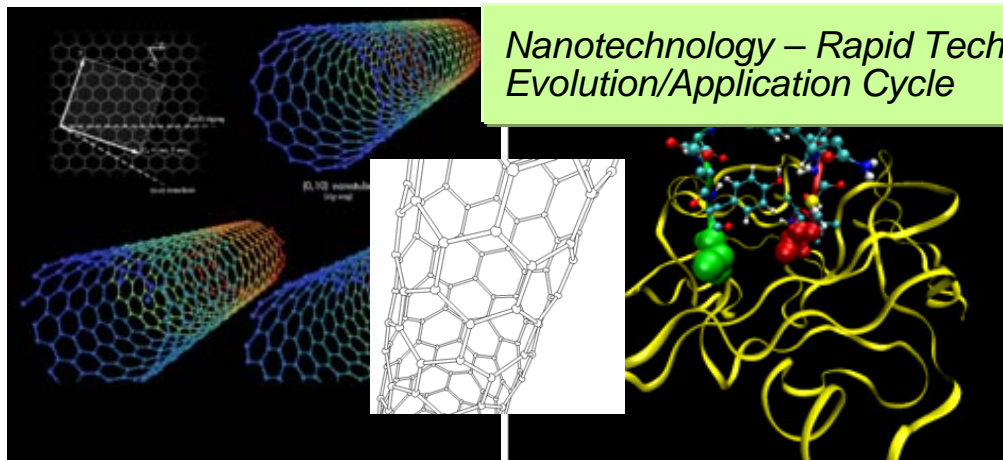
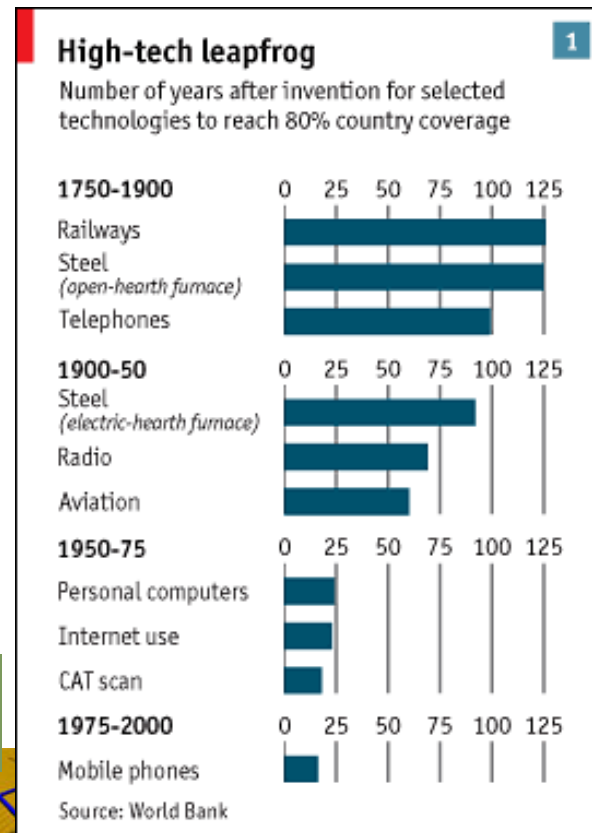
There are students in China, Australia, Austria, Bangladesh, and the USA who collaborate on projects everyday



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

Technology Development Outpaces Traditional Acquisition (and getting faster)



“Moore’s Law” → Computing doubles every 18 months

“Fiber Law” → Communication capacity doubles every 9 months

“Storage Law” → Storage doubles every 12 months

Defense Acquisition Pace

F-22	Milestone I:	Oct 86	IOC:	Dec 05*
Comanche	Milestone I:	Jun 89	IOC:	Sep 09

* Computers at IOC are 2,000 X faster, hold 130,000 X bits of information than they did at MS I

**Technology growth is non-linear...
Acquisition path has been linear**

DoD Acquisition Programs: *Example Timelines and Cost*



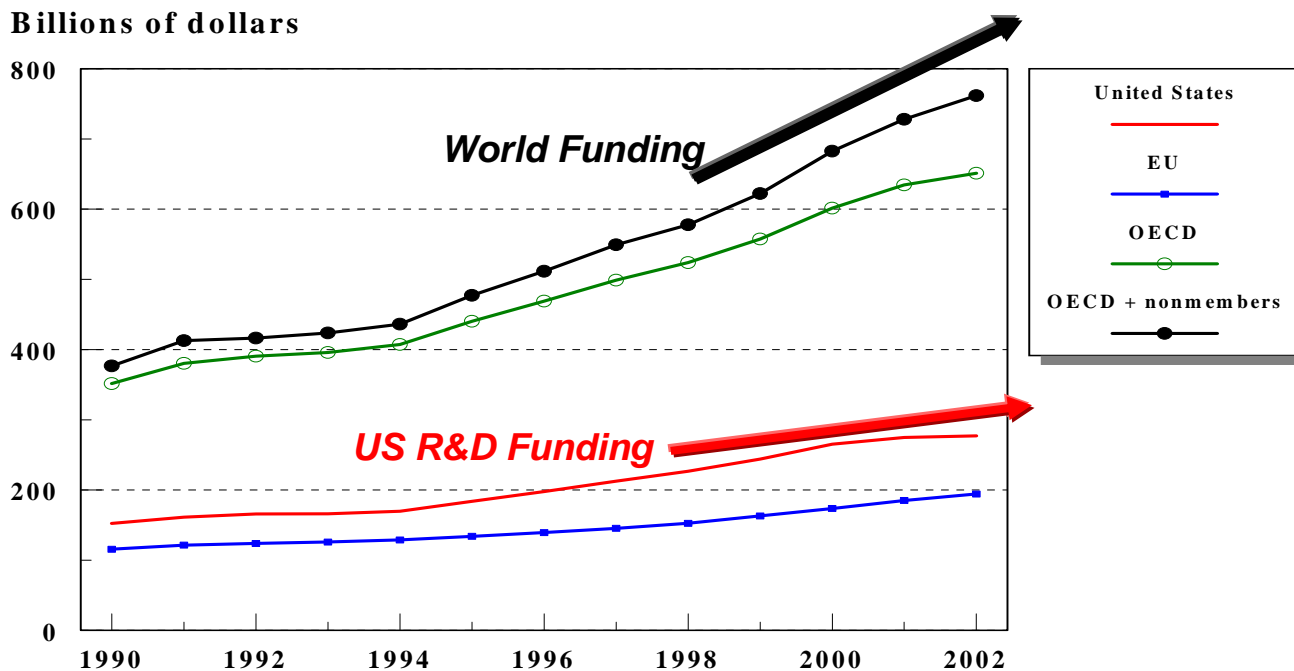
Program	Service	MS I/II	IOC	Total RDT&E
F-22A	Air Force	OCT 1986	DEC 2005	\$29B
Cobra Judy Replacement	Navy	SEP 2004	SEP 2011	\$1.5B
Future Combat System (FCS)	Army	MAY 2003	DEC 2014	\$30B
Joint Strike Fighter	DoD	NOV 1996	USMC: MAR 2012 USAF: MAR 2013 USN: MAR 2013	\$46B
Virginia Class Submarine	Navy	AUG 1994	NOV 2006	\$5B
SBIRS High	Air Force	OCT 1996	SEP 2008	\$8B



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.

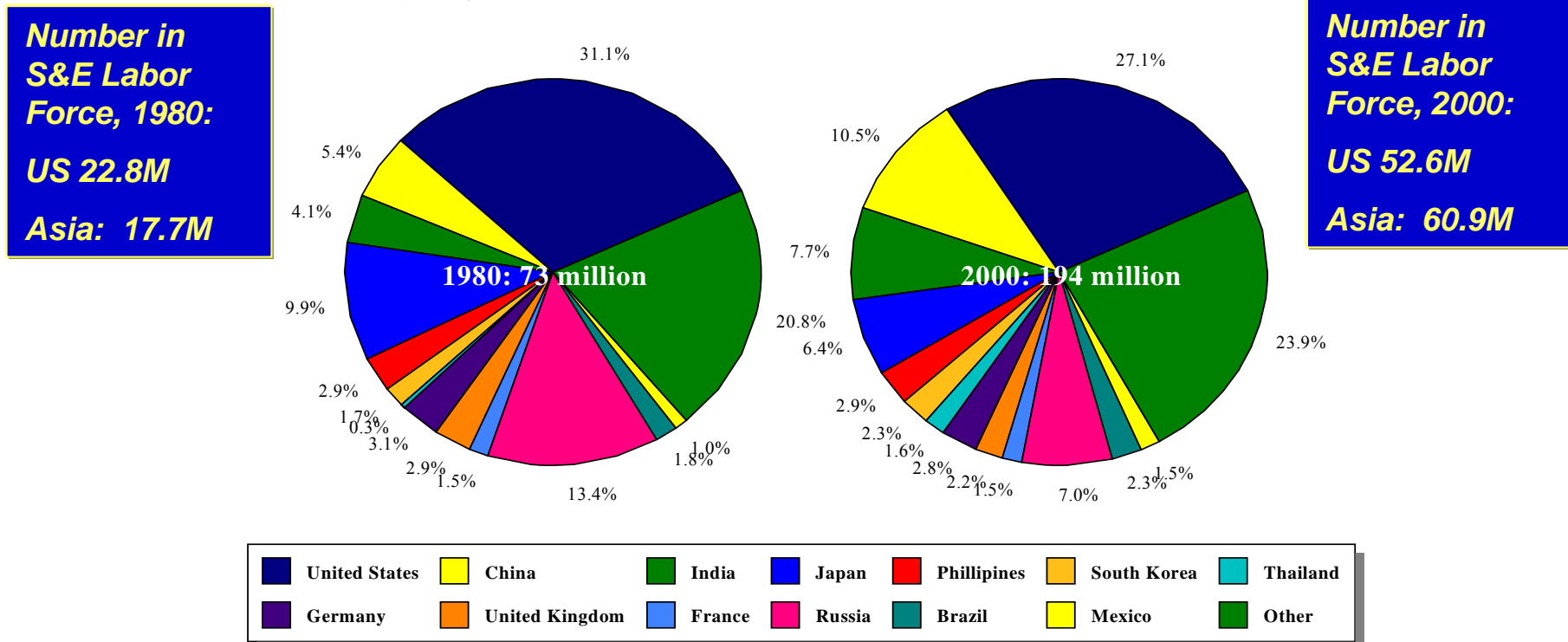
SOURCE: OECD, Main Science and Technology Indicators database, November 2004

Growth of Educated Asian Population



- International S&E labor force data can only be approximated.
- From 1980 to 2000, US – 4%; Asia +5%; Europe - 4%

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

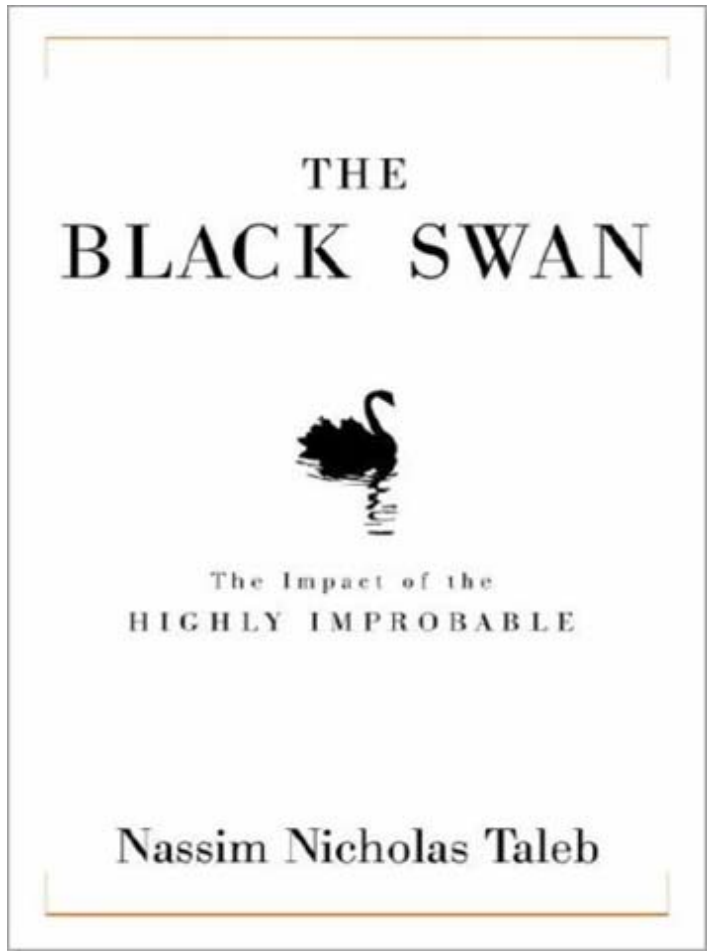


SOURCE: Adapted from R.J. Barrow and J. Lee, Center for International Development: International Data on Educational Attainment, 2000

The “Black Swan” Syndrome



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

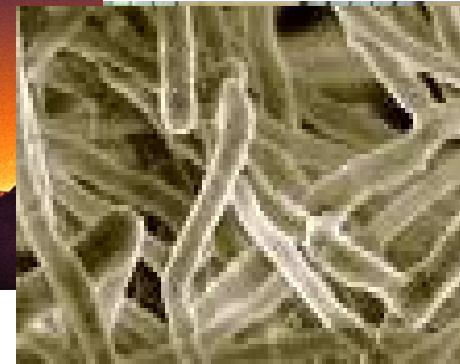
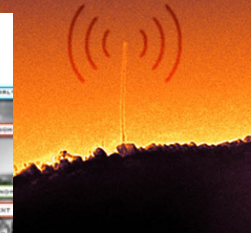
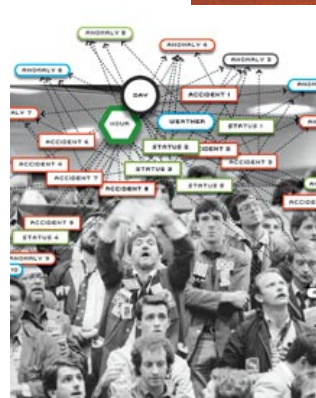
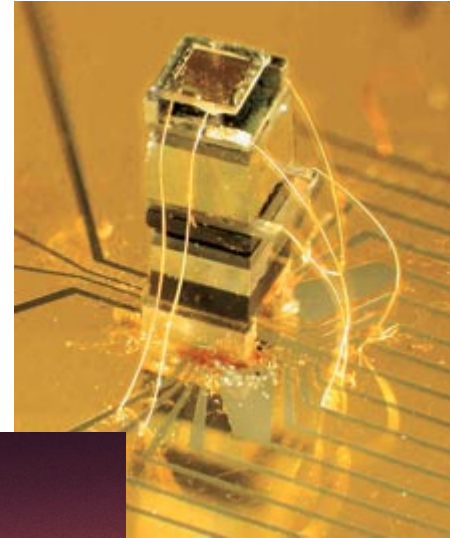
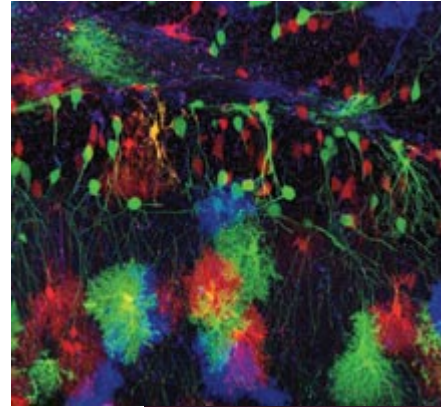


- “Black Swans”: ***large-impact, impossible to predict, and rare event beyond the realm of normal expectations***
 - 9/11, Google, internet bubble
- “Outside context problem”: ***Problem outside a given groups experience, with an immediate, ubiquitous and lasting impact upon it***
 - Perry’s Black Ships 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

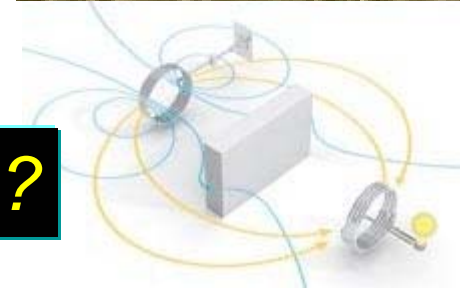
March/April 2008 MIT Innovations List of 10 Emerging Technologies



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



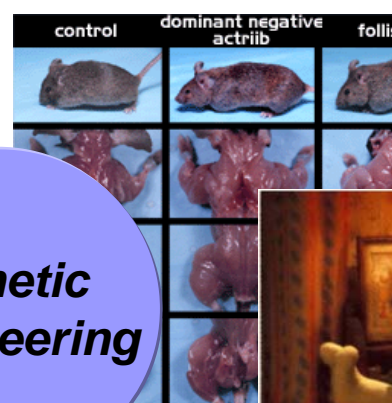
But Where is the Black Swan?





Commercial / Military Hybrids

- 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



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Genetic Engineering

Future Processors



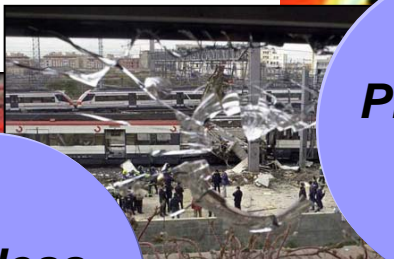
Proliferant Lasers



Unmanned Vehicles

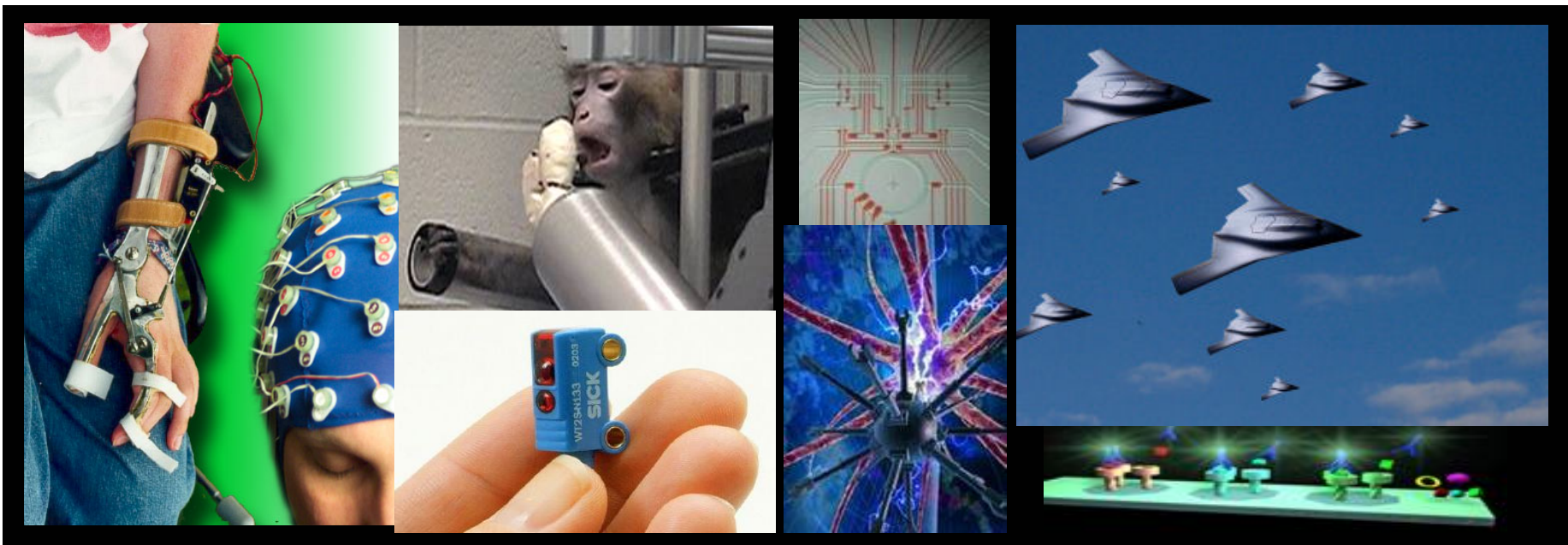


Wireless Devices



Implications

- **Greater base of technology development, more agility than previous**
- **Need Enhanced Technology Scouting and Investment**
- **Technology increasingly hybrid, commercial/military**



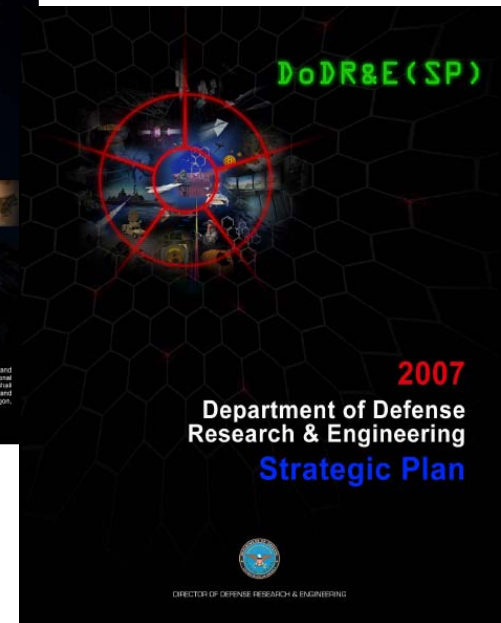
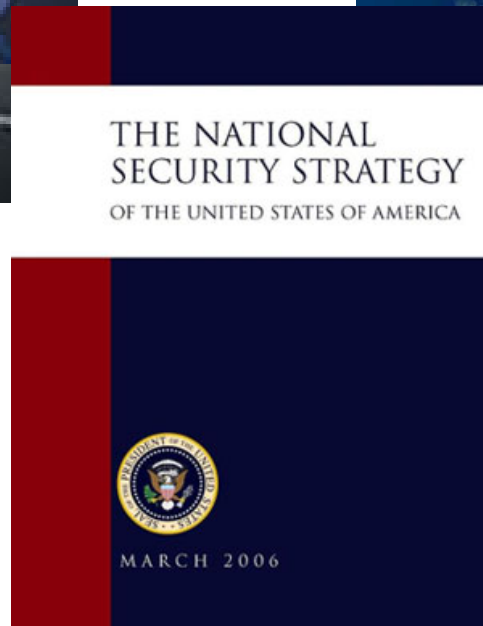
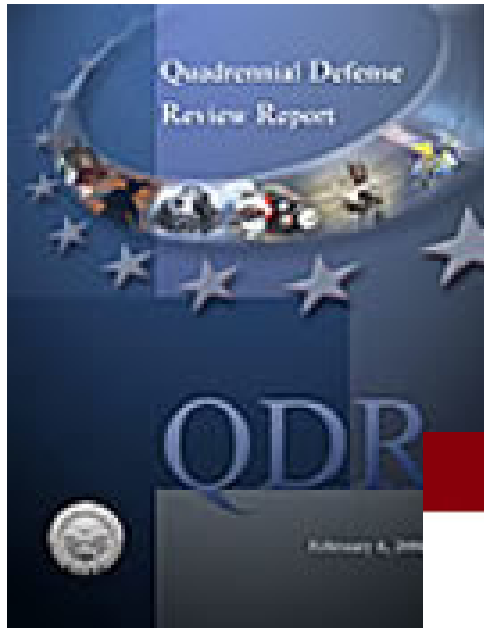
Potential for technology surprise may be increased

Where are we going?

S&T Strategy and Plans

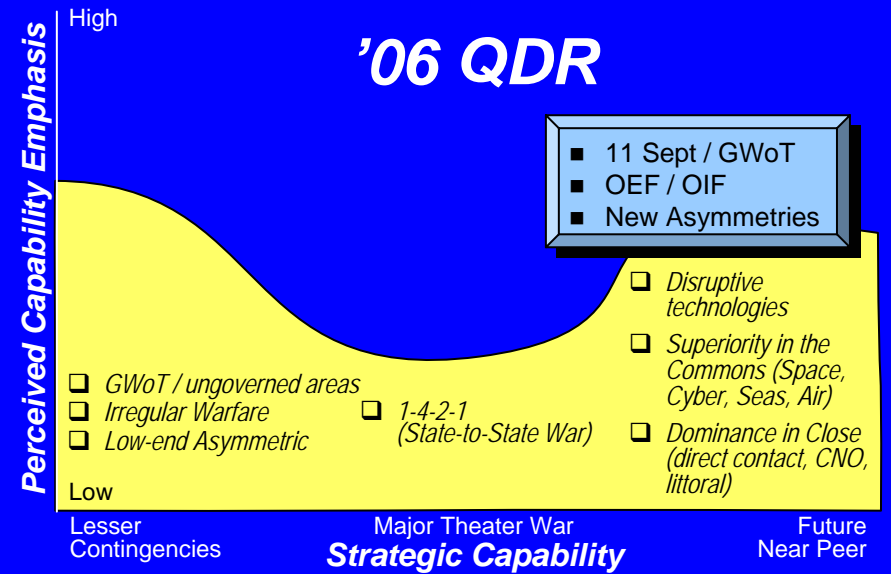
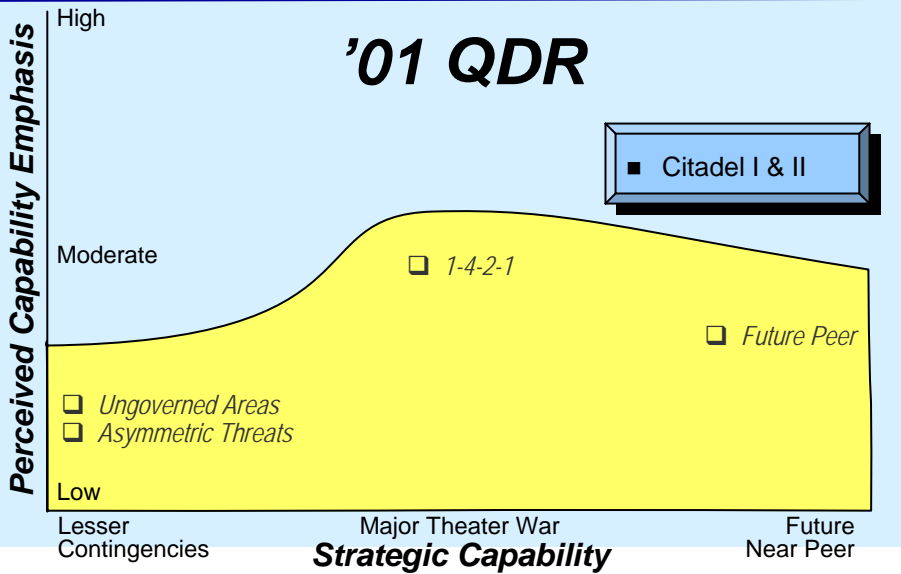
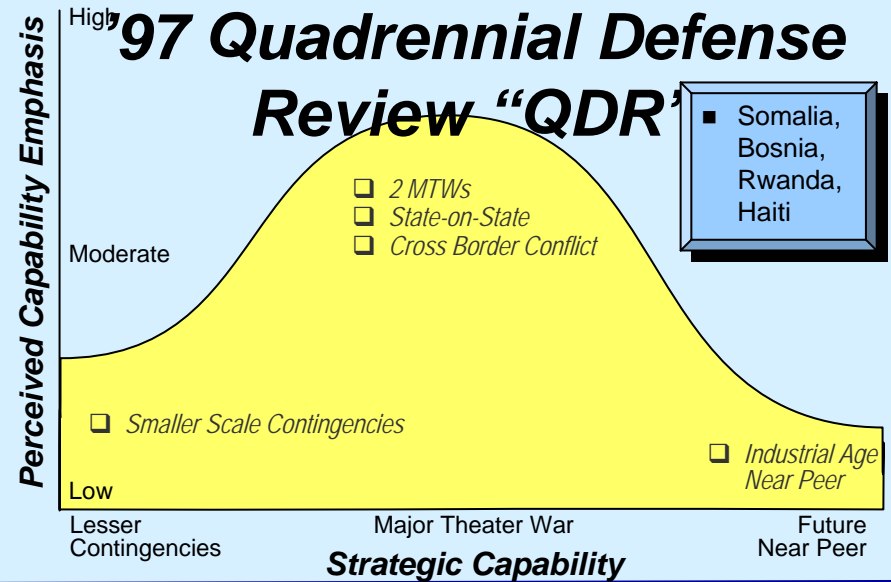
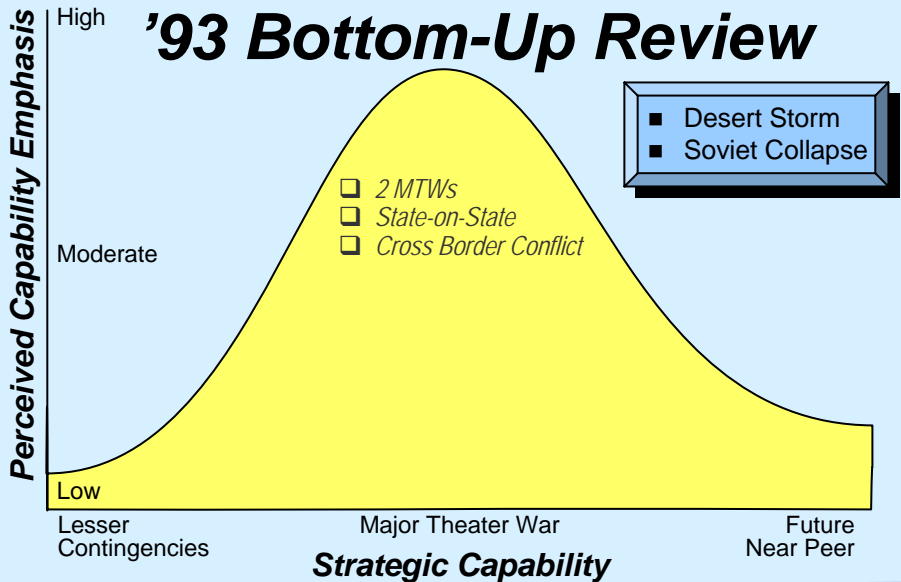


Defense Science and Technology Strategy and Planning



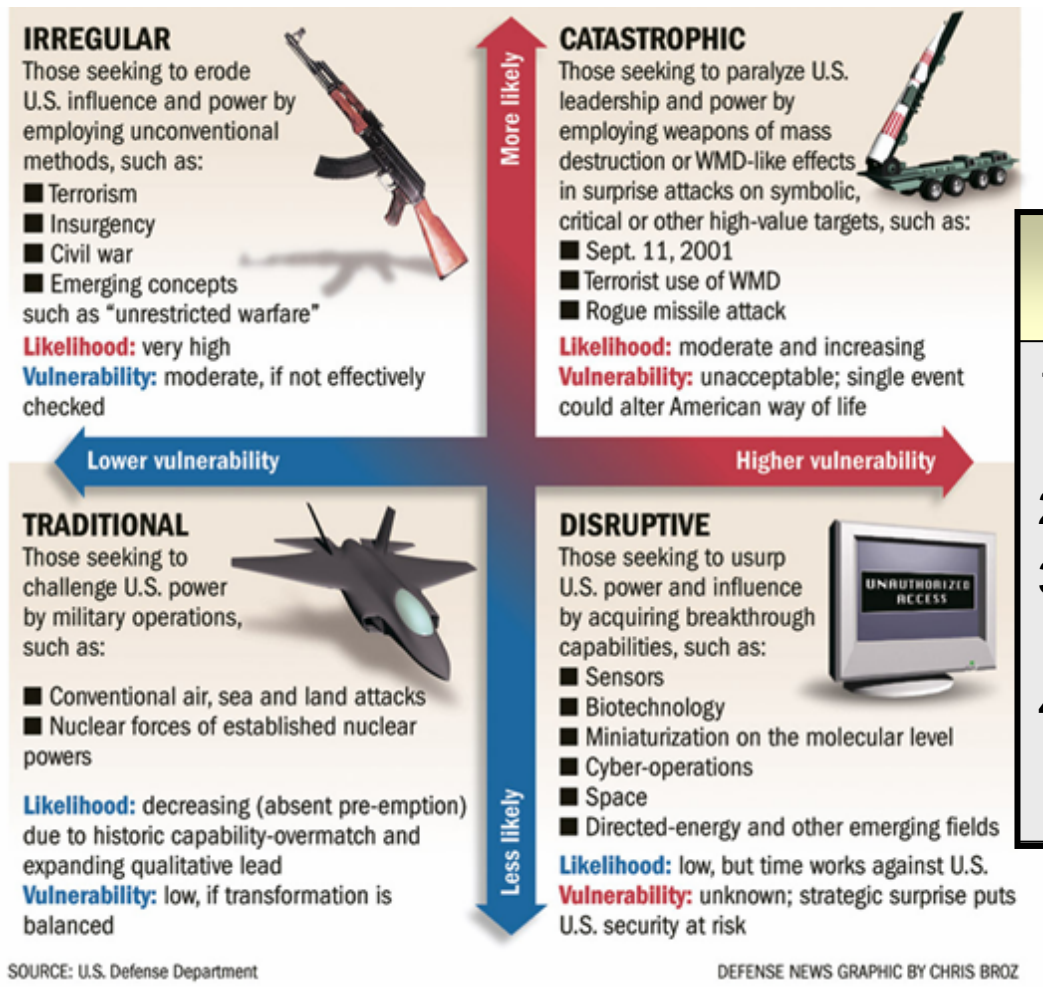


Decade of Strategic Evolution





2006 QDR Challenge Construct



SOURCE: U.S. Defense Department

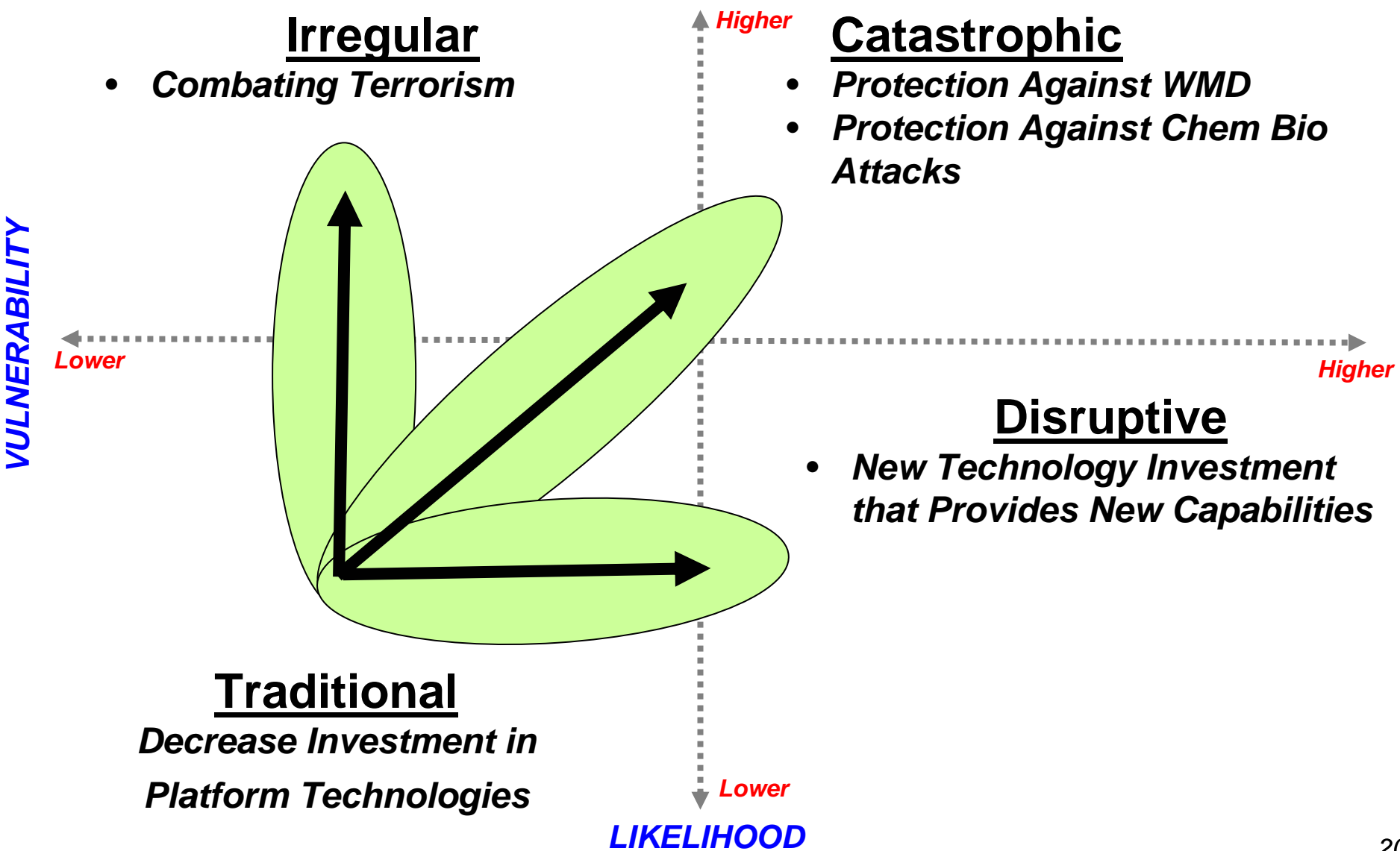
DEFENSE NEWS GRAPHIC BY CHRIS BROZ

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



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

Science and Technology Enabling Technology Priorities



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 - **Biometrics and Biological exploitation**
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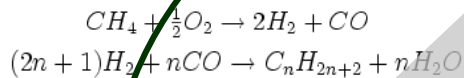
In Blue—Areas with Substantial Increases in FY08/09 President's Budget Request

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, alcohols, hydrogen, etc.)
- Renewables (e.g. solar, geothermal, wind)
- Novel supply (e.g. fuel cells)
- Exotics (e.g. isomers)



Demand

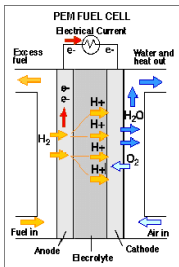
- Conservation Initiatives
- Fixed base
- Tactical base
- Platforms
- Efficiency
- Life-Cycle Cost



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

Convergence for Energy Security

Assured Distribution



Ongoing Activity, Goals 1 and 2

- Installations -



- Each Service has active programs or pilots to reduce installation energy and increase resilience
- Example programs

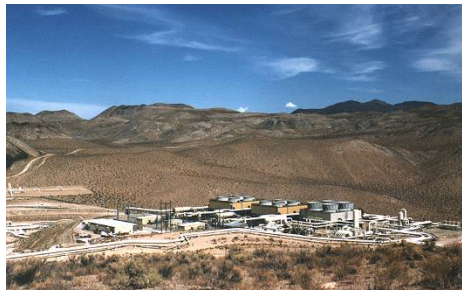
Army

- **Net zero pilot, Ft. Irwin**
 - \$25M upfront cost
 - \$105M savings in 5 years
- **Tent foam, Iraq**
 - \$95M upfront cost
 - Estimated reduction \$300K+/day
- **Energy efficient housing demo, Ft. Belvoir**



Navy

- **Existing geothermal plant, China Lake, CA**
 - 270 MW (supports ~100,000 households)
- **Building geothermal plant at NAS Fallon**
 - Working with Hawthorne Army Depot



Air Force

- **Infrastructure Energy Plan**
 - Facility energy intensity -13% since FY03
- **New solar farm, Nellis AFB, NV**
 - Powers 25% of base
- **Testing waste to energy systems**



Ongoing Activity, Goals 1 and 2

- Platforms -



- Each Service has active programs or pilots to reduce platform energy and increase resilience
- Example programs

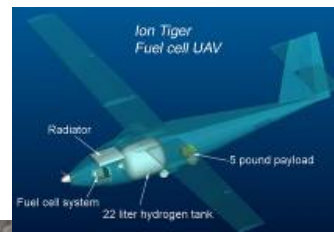
Army

- **Fuel Efficient Ground Vehicle Demonstrator**
–30-40% increased efficiency
- **Thermal Management**
- **Rotorcraft Advanced Turbine Engine**
–Up to 25% efficiency with increased horsepower



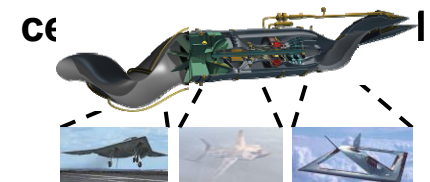
Navy

- **Solid oxide fuel cell cells**
- **Reduced friction coatings for propellers**
–5+% increased efficiency
- **UAVs/UUVs**



Air Force

- **Advanced Turbine Research**
–25% increased efficiency
- **Efficient engines for UAVs and generators**
–20% increased efficiency
- **Synfuel certification ongoing**
–Goal: Fleet



UAV: Transports ISR



President's Budget Request FY2009 For S&T— A Reflection of the Changed Priorities

- PBR09 S&T Request continues the realignment initiated in FY08 to address capability gaps identified in the 2006 QDR
 - 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

President's Budget Request FY2009 For S&T— A Reflection of the Changed Priorities (Cont)



- 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



President's Budget Request FY2009 For S&T— A Reflection of the Changed Priorities (Cont)

- 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 **

** **Note:** *Cyber protection is funded in DARPA BA 6
Air Force funding for Blackswift is in BA 7*

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

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

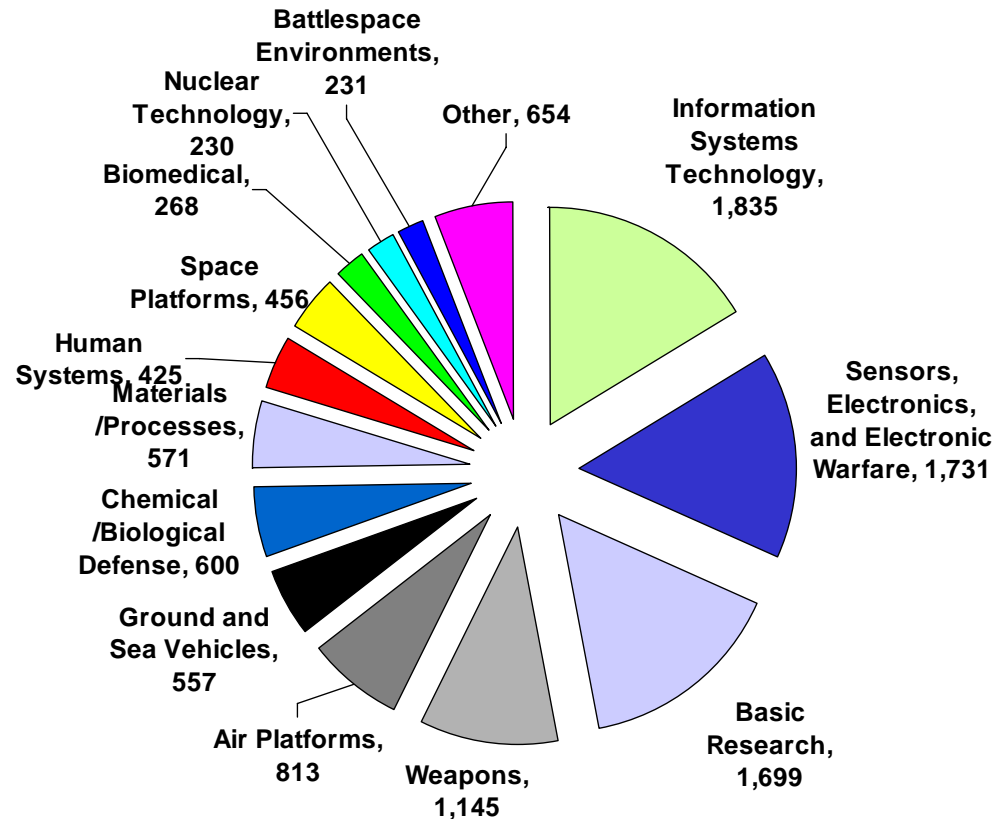


Characterization of the FY09 DoD S&T Program



• 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)

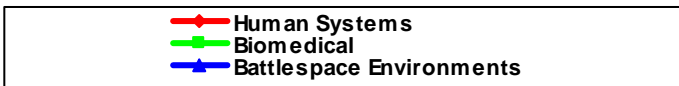
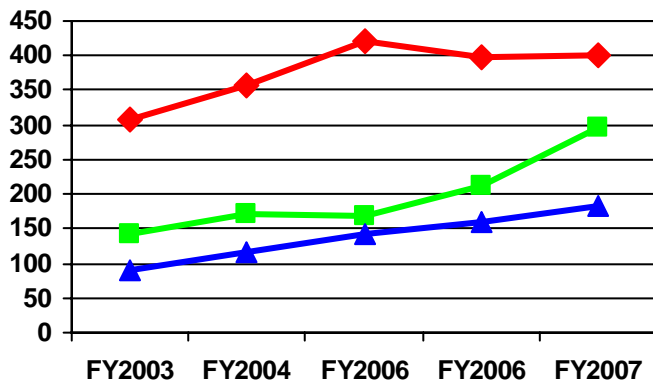


DoD S&T program is focused on “sensing and shooting”

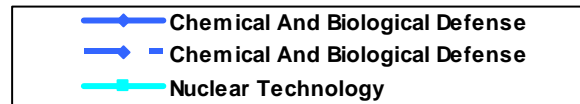
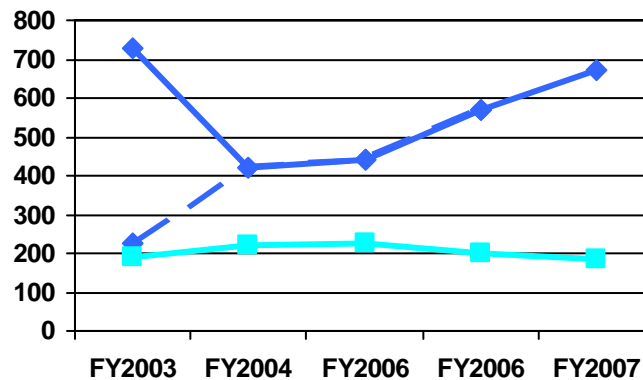


Funding By Technology (Reliance) Areas

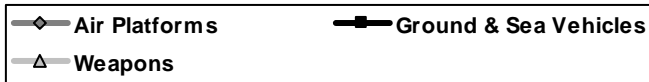
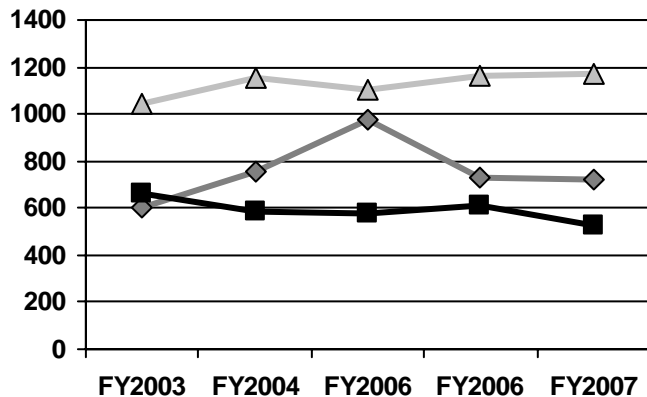
Irregular



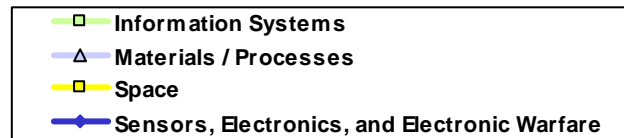
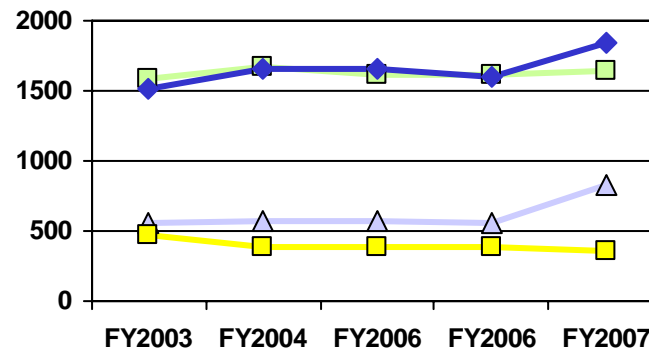
Catastrophic



Traditional

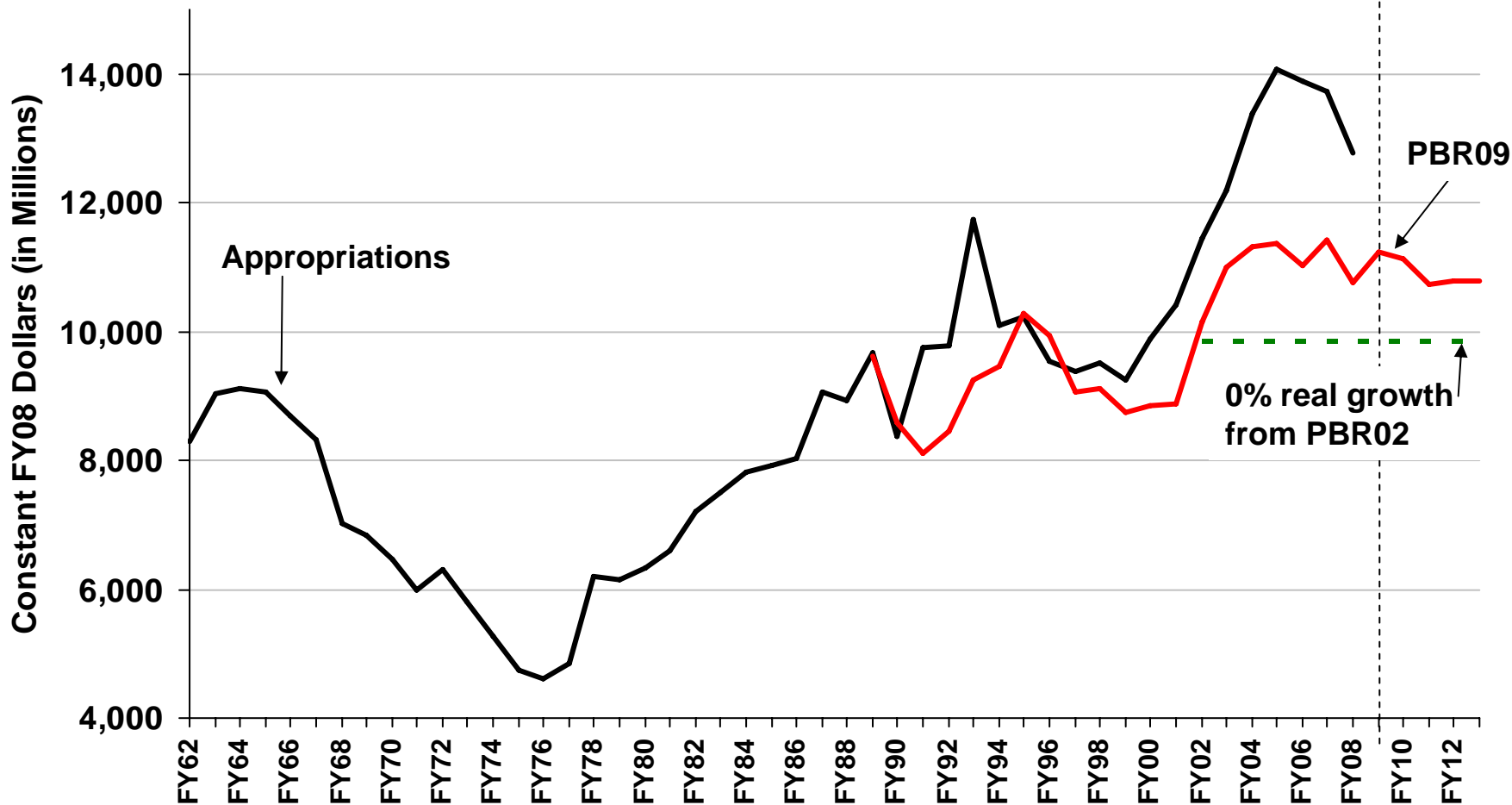


Disruptive



DoD S&T – Historical Context

- In FY08 Constant Dollars -



In FY03, includes \$203M allocated to Def Emergency Response Fund (DERF) S&T in a separate DoD transfer account

FY09 S&T request is among the highest



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

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 capabilities

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

Kinetic

Most of These Capabilities are Joint, Coalition Centric



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

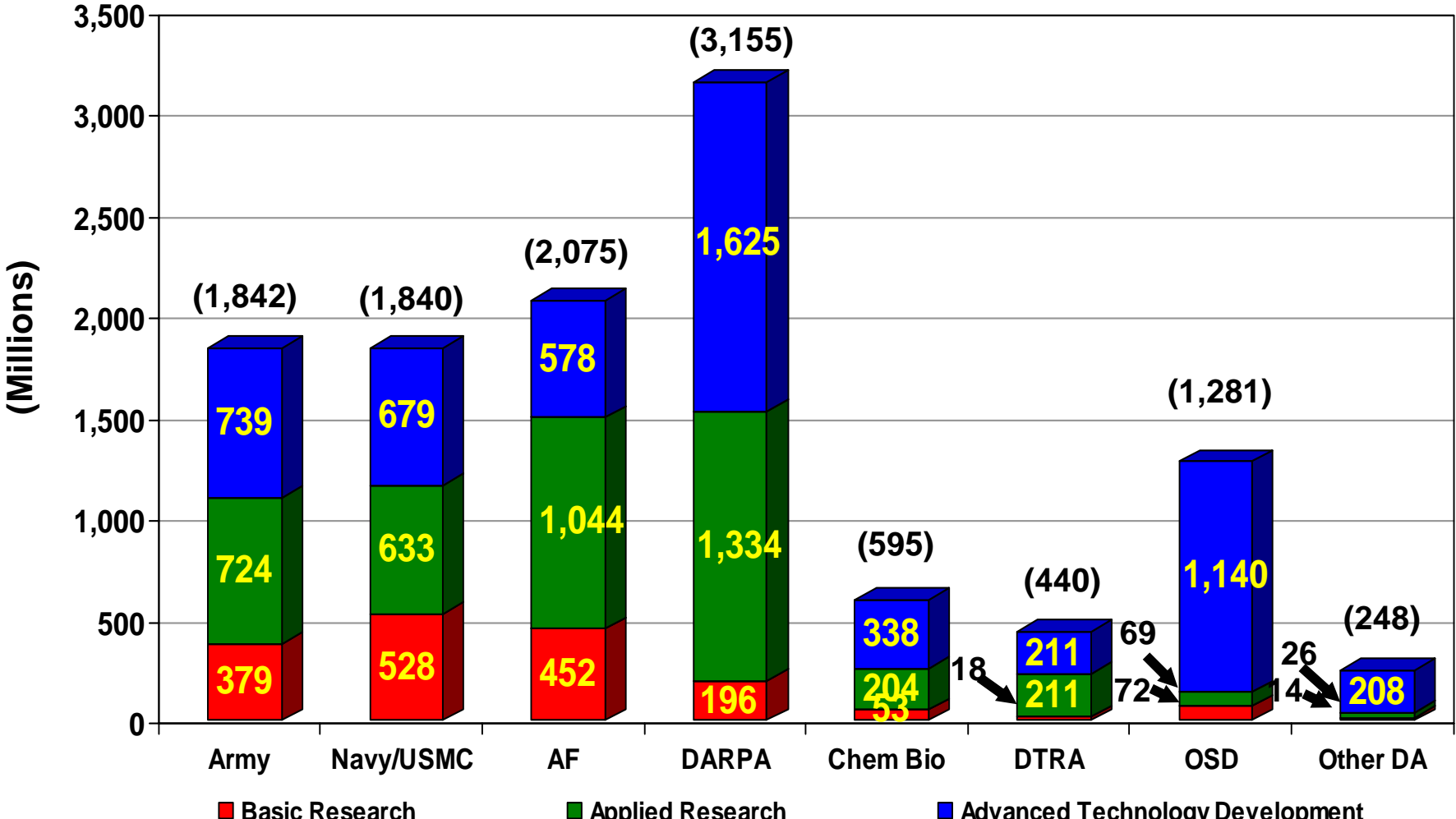
All These Capabilities are Joint, Coalition Centric

FY09 DoD S&T Budget Request



Total FY09 S&T request = \$11.48B

Total FY08 S&T Request = 10.77B
 Army = 1,728, Navy = 1,667, AF = 1,964, DARPA = 3,033, ChemBio = 610, DTRA = 401, OSD = 1,166, Other DA = 201

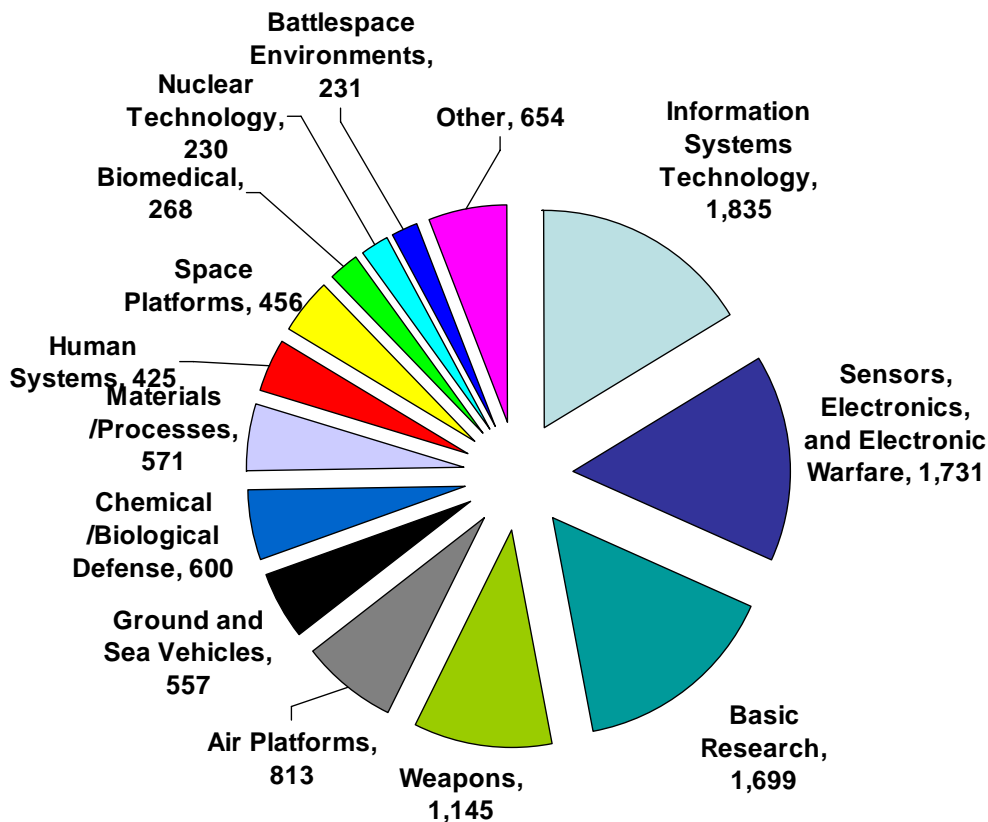




Where is the DoD S&T money going?

• 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.....***

PBR09 S&T Request Addresses Capability Gaps



- PBR09 S&T Request continues the realignment initiated in FY08 to address capability gaps identified in the 2006 QDR
 - 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

PBR09 S&T Request Addresses Capability Gaps (Cont'd)



- 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

PBR09 S&T Request Addresses Capability Gaps (*Cont'd*)



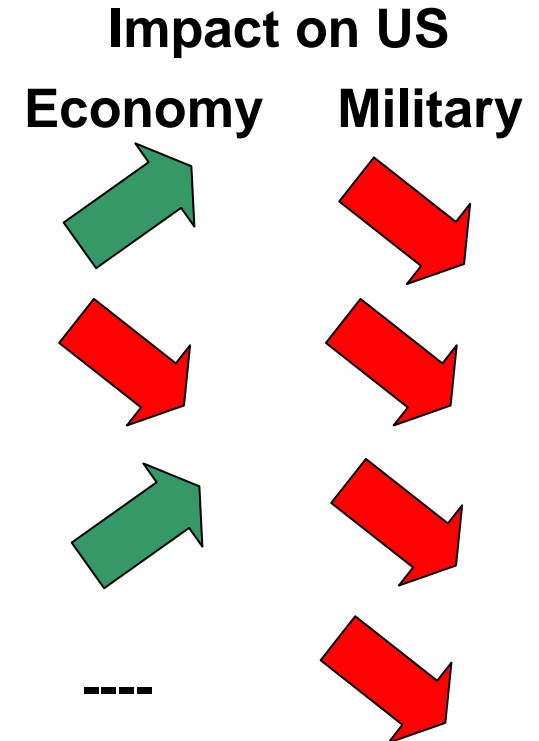
- New technology/emphasis areas (*Cont'd*)
 - Increased protection for dismounted troops and ground forces
 - Research in plasma and meta-materials to address emerging threats
 - Cyber protection **
 - Hypersonics/Prompt Global Strike (Blackswift) – New technology prototype **

** **Note:** *Cyber protection is funded in DARPA BA 6
Air Force funding for Blackswift is in BA 7*

Summary: A Changing World



- **Globalization of S&T**
 - Creativity and agility are needed!
- **Generation of new Scientists and Engineers**
- **New Emergent Technology**
- **Pace of Technology Development**



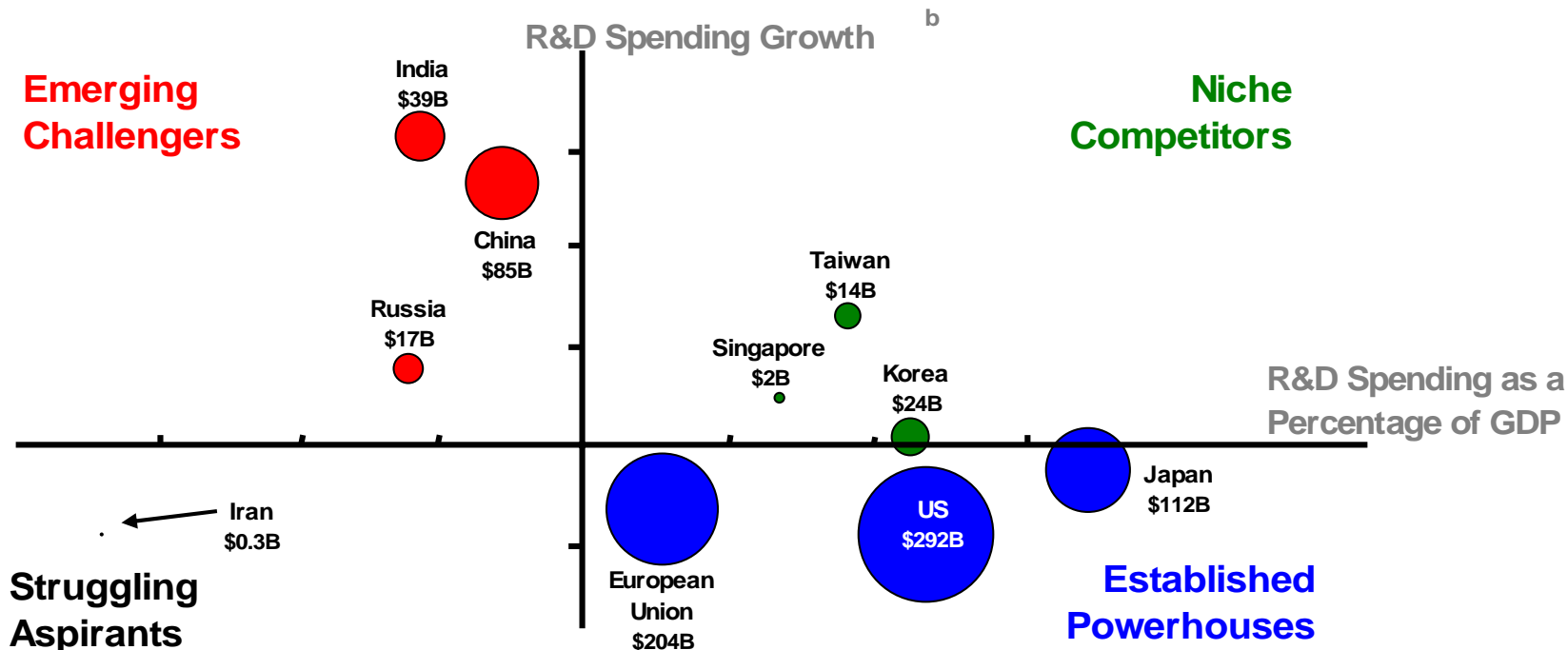
***Net Effect: Forcing Factors have changed
DoD /US Strategy evolving, but immature***



Global Technology (R&D) Spending and Growth

The R&D Spending Landscape - Selected Entities^a

(Circle size reflects R&D spending levels.)



^aR&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.

^bGrowth 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, Science and Technology 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.

The Evolution to New Ideas



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

“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

Forecasting Future Disruptive Technology—Mass Collaboration



- 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 . . .

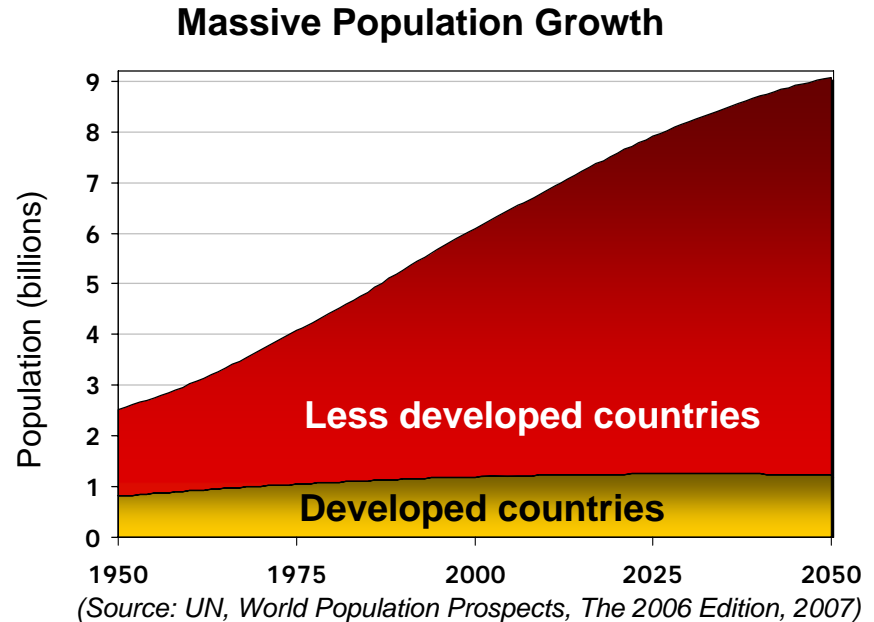


Using mass collaboration as the tool for “*Effective Forecasting*”

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



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

Disruptive Technologies

Frequently Take a Forcing Function



Technology	Approximate Date Of First Lab Demo	Approximate Date Of First Military Applications	
Radio	1901	1914	} <i>World War I</i>
Airplane	1903	1916	
Vacuum Tube	1906	1915	
Mechanized Tank	1916	1916	} <i>World War II</i>
Liquid-Fueled Rockets	1922	1944	
Radar	1925	1939	
Gas Turbine	1935	1944	
Digital Computer	1943	1945	
Ballistic Missile	1944	1945	} <i>Cold War</i>
Nuclear Weapons	1945	1945	
Transistor	1948	1957	
Inertial Navigation	1950	1955	
Nuclear Propulsion	1950	1954	
Artificial Earth Satellites	1957	1960	
Integrated Circuit	1960	1970	

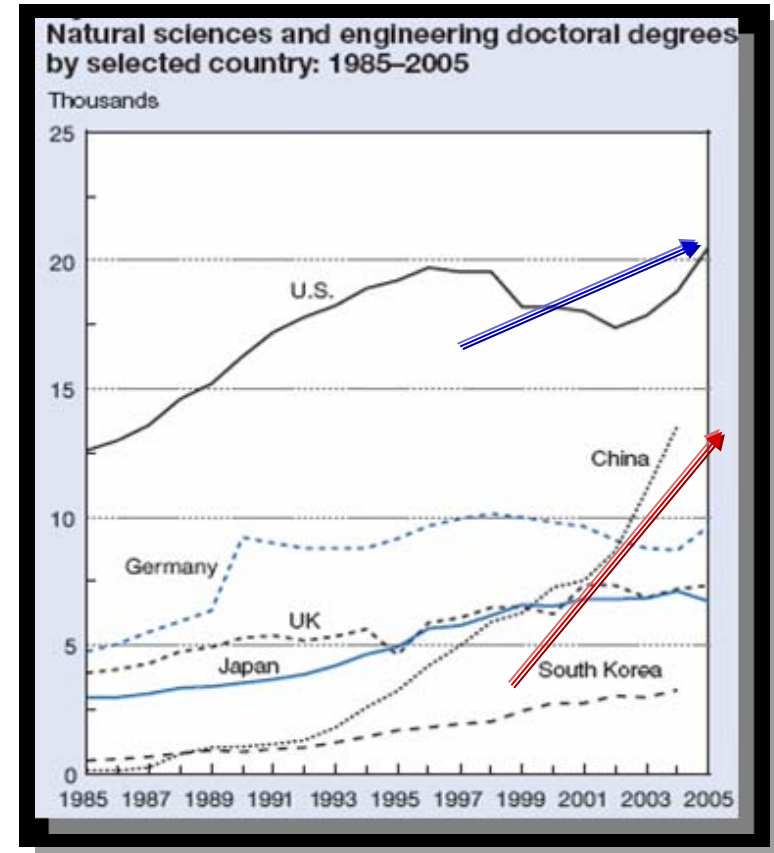
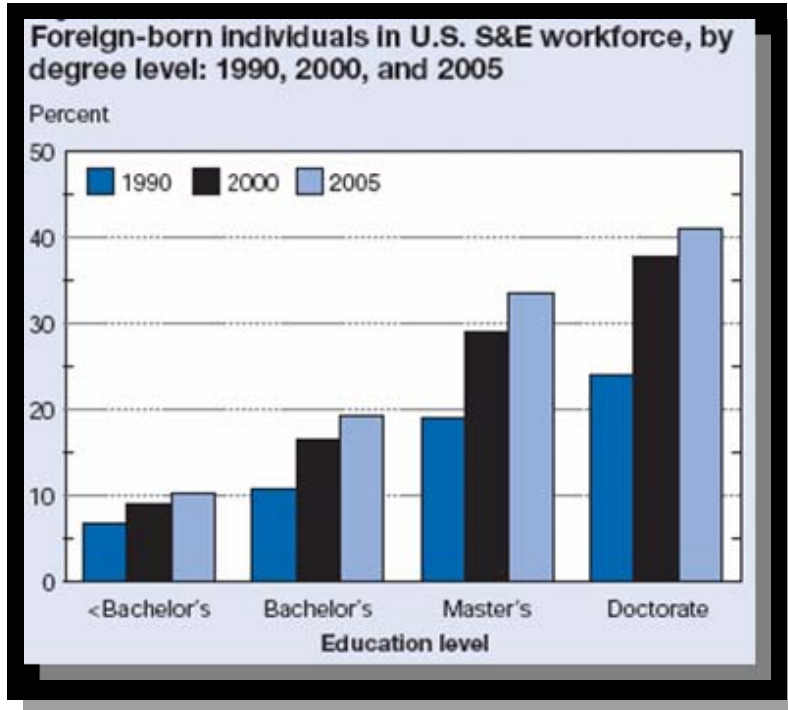
Laser
Precision

One function of S&T – Keep the pantry stocked

Comparison of Scientists & Engineers (S&Es)



Number of Foreign Born in US S&T Workforce has Quadrupled over 15 years. (# of Non-US Citizens is Unknown)



Number of U.S. doctoral degrees awarded in S&E has increased three decades in a row, however, virtually all of the recent growth reflects a rising number of degrees to non-U.S. citizens: 60% in engineering and computer science and nearly 45% in the physical sciences.



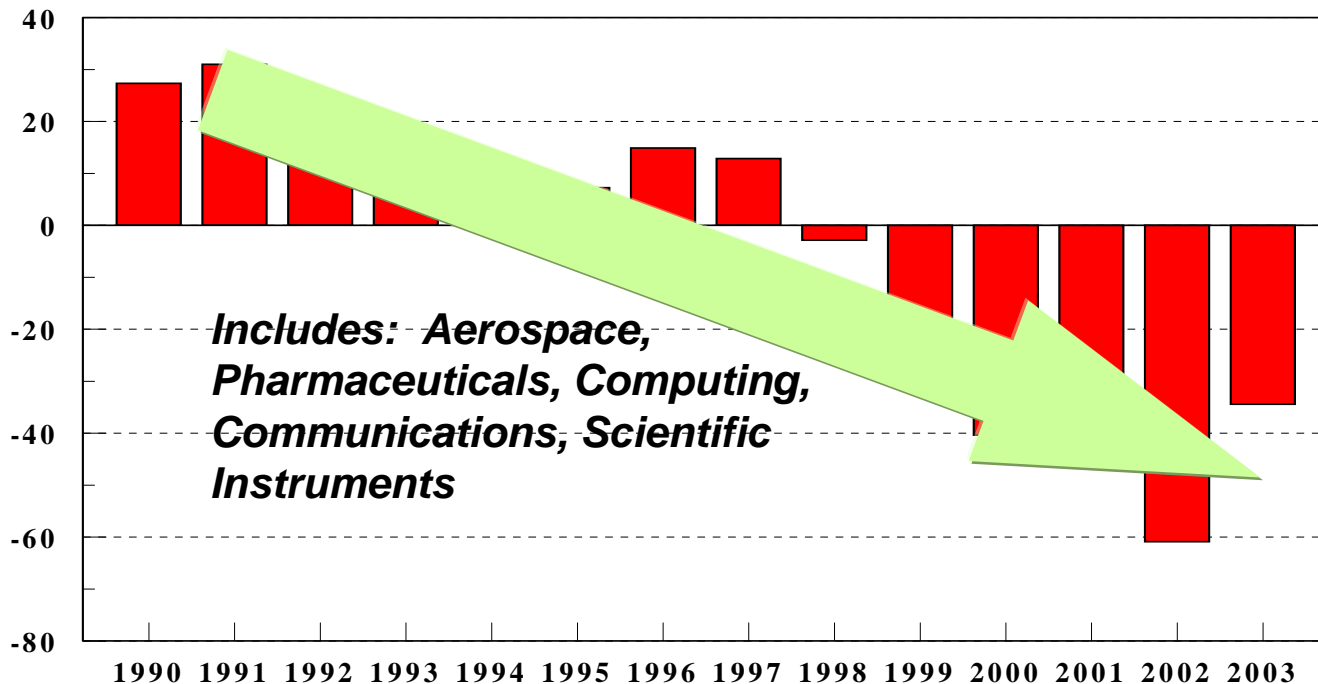
U.S. trade balance – high tech industries

- 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

Enhancing Technology Transition is Changing the Management Model

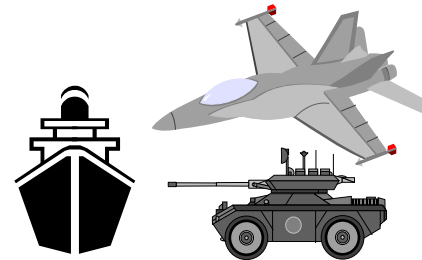


All Services are moving their acquisition processes

FROM



S&T



Acq

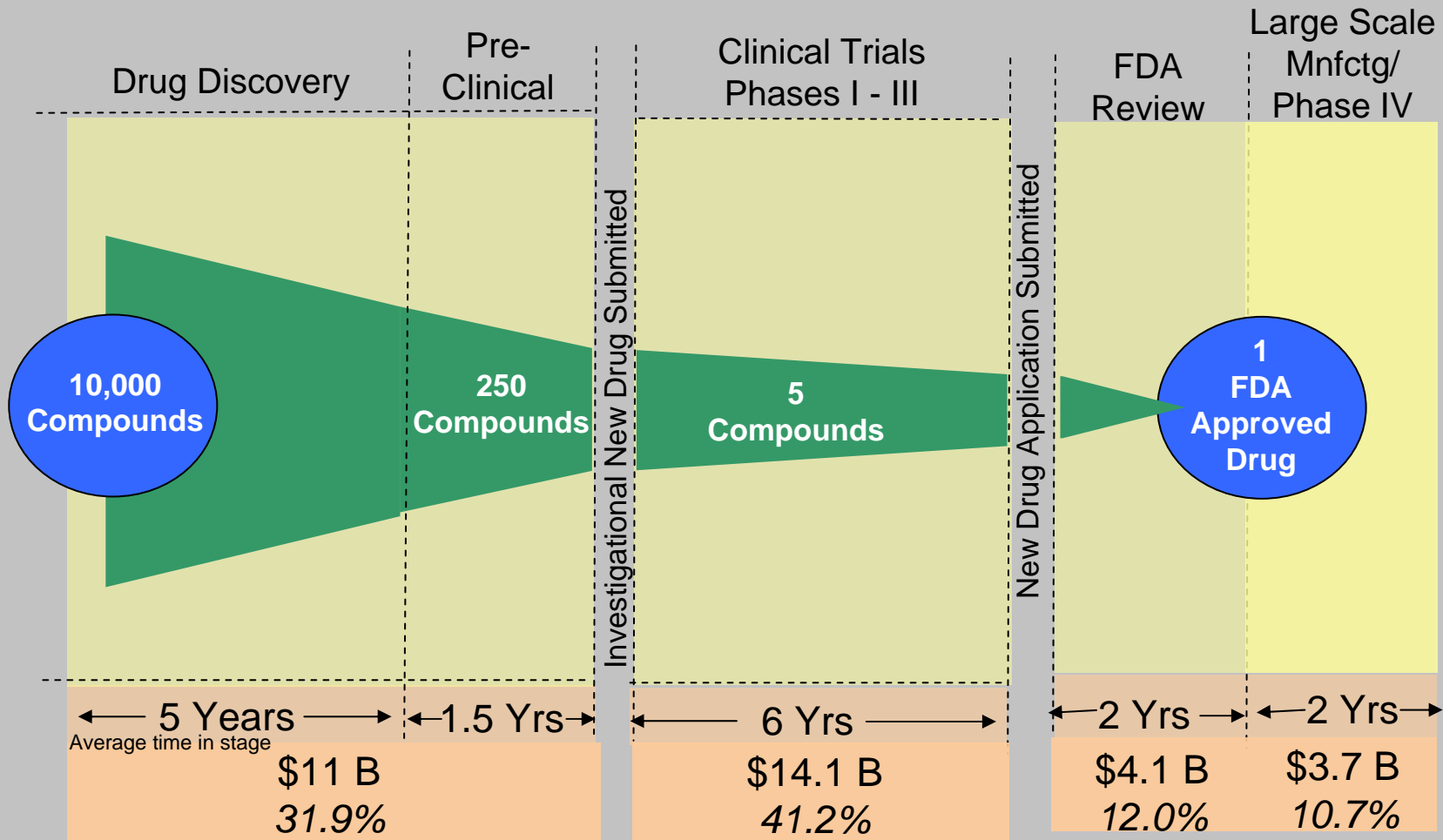
TO



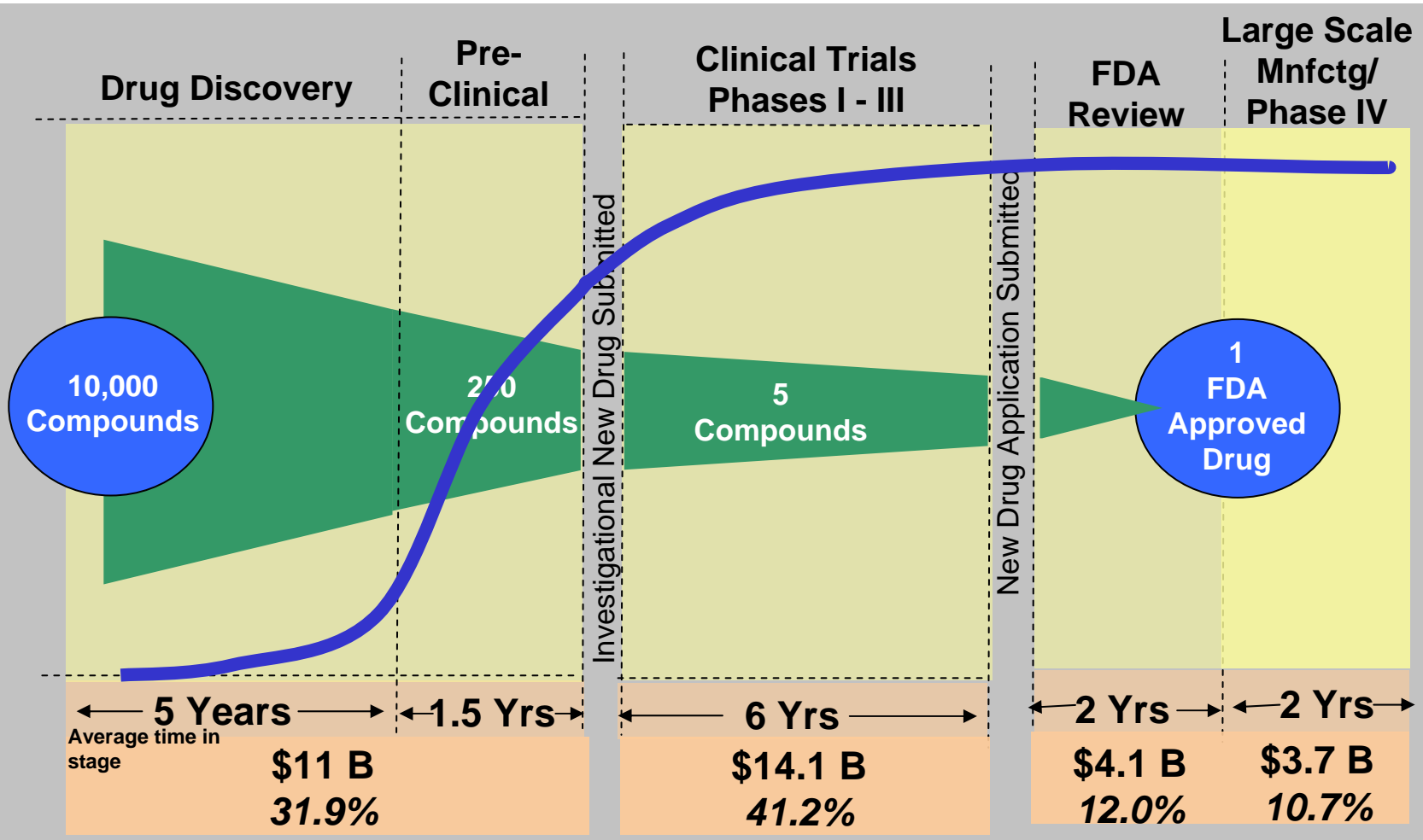
Developing the Right Technology is a Contact Sport



Biopharmaceutical R&D



Source: Pharmaceutical Research & Manufacturers of America, Pharmaceutical Industry Profile 2005 (Washington, DC: PhRMA, March 2005).



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Artificial Earth Satellites	1957	1960	
Integrated Circuit	1960	1970	
Laser	1961	1967	
Precision Weapons	1965	1967	

One function of S&T – Keep the pantry stocked



Overview

- **A Changing World**
- **A Quick look at the Quadrennial Defense Review**
- **Implications of the QDR on the DoD Research and Engineering Investment**



You never got the hang of the new technology, did you Miss Faversham?

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

