DoD Science & Technology Priorities
May, 2014

Mr. Bob Baker
Deputy Director, Plans & Programs,
Assistant Secretary of Defense (Research & Engineering)

Theme

- ***Continue aligning S&T investment to enable development of capabilities consistent with the January 2012 strategic guidance****

*** Sustaining U.S. Global Leadership: Priorities for the 21st Century Defense, Jan 2012**

- ***"U.S. Armed Forces will be smaller and leaner, but they will be agile, flexible, ready, and technologically advanced." "Protect investments in key technology areas and new capabilities…"***

- Overview, DoD *FY 2014 Budget Request*, Apr 2013

- ***DoD continues to support a strong S&T investment***

Outline

- ***Changes, Challenges & Priorities***
- *FY2014 S&T President's Budget Request*

The Changing National Security Mission

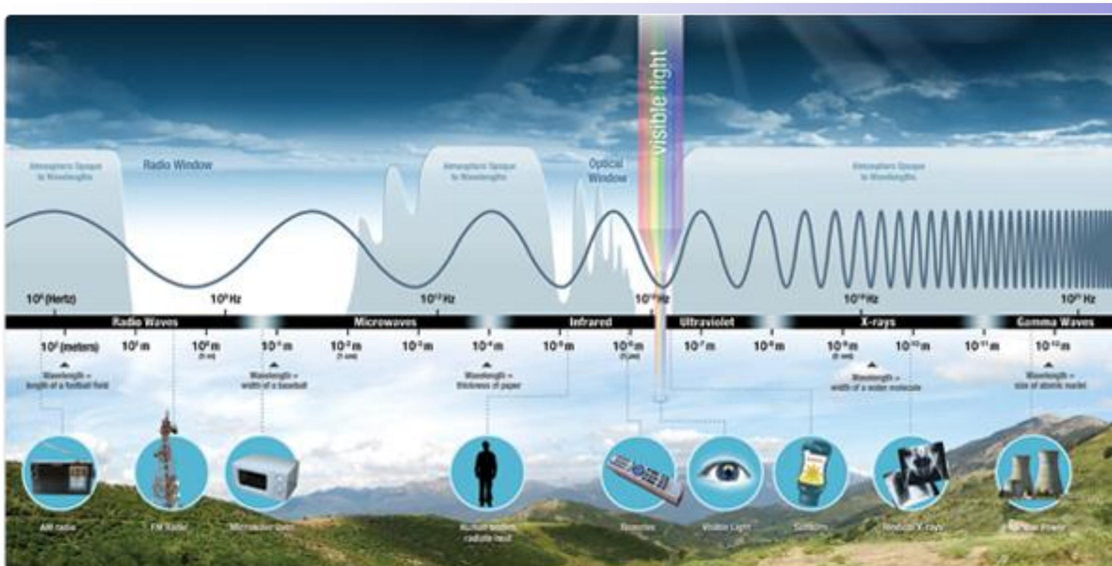
- **Proliferating WMD capability**
- **Adversaries will increasingly leverage commercial technology to challenge U.S. military capabilities**
- **New emerging challenges, e.g., energy security, climate change, cyber security**
- **Policing and peacekeeping in a coalition of many, in contrast to warfighting**
- **Balancing current vice future requirements**
- **Maintaining conventional and irregular warfare capability**
- **Soft power often more appropriate than hard power**
- **Failing/failed rather than aggressor states are a big challenge**
- **Need to rebalance our focus from Iraq and Afghanistan toward the security and prosperity of the Asia-Pacific region**

**** MG Michael Flynn, DCS, Intelligence, ISAF, Afghanistan***

The Anti-Access & Area Denial (A2/AD) Challenge

- **The Department sees A2/AD as an expanding global challenge**
- **A2/AD is the development of capacity by our adversaries to degrade US/Allied capabilities and prevent freedom of movement**

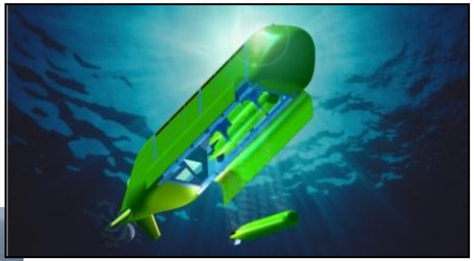
Rise of the Commons
Cyber, Electromagnetic Spectrum & Space



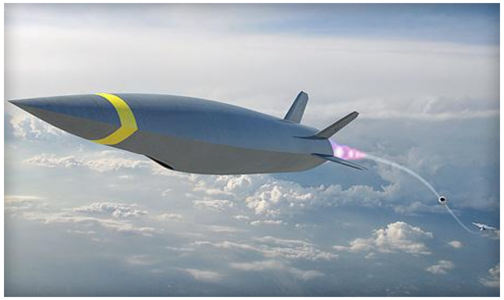
Military operations increasingly depend on being able to operate in places "no one owns" – the Commons

DoD Needs to Develop New Ways to Project Power

- ***Improved Intelligence, Surveillance, & Reconnaissance***
- **Electronic Attack / Electronic Protection**
- ***Surface to Surface Ship Missiles***
- ***Ballistic and Cruise Missile Defense***



BAE Systems Sea Lightning EX system



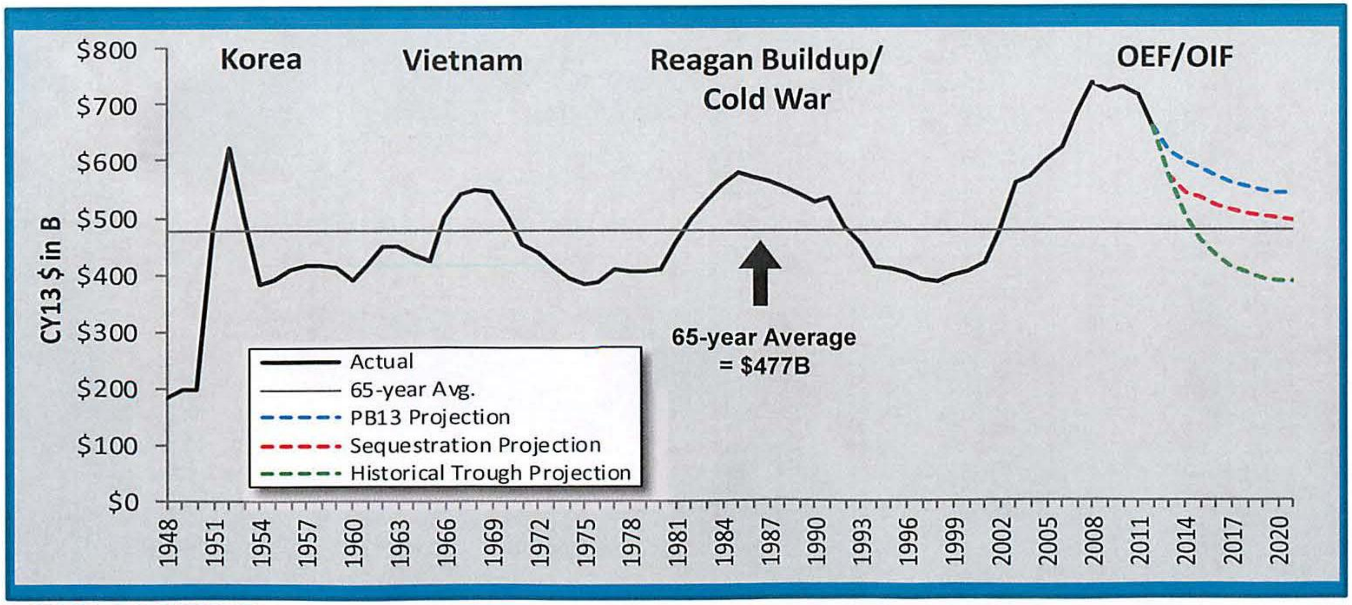
- ***Improved Precision Strike***
- **Cyber and Space Capabilities**
- **Undersea Warfare**
- ***Advanced Air Defenses***

Technologically advanced capabilities needed for the future

The Reality….

"Our current security challenges are more formidable and complex than those we faced in downturns following Korea, Vietnam, and the Cold War. There is no foreseeable "peace dividend" on our horizon."

GEN DEMPSEY, CJCS
Testimony to SASC, 12 Feb 2013

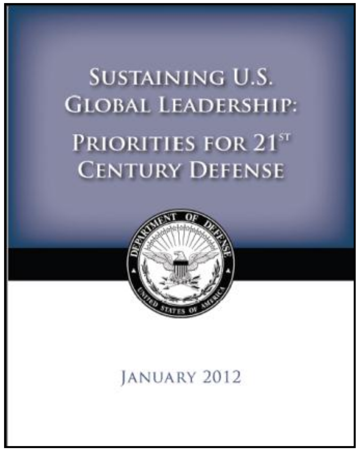


UNCLASSIFIED

2012 Defense Strategic Guidance

"The Department will make every effort to maintain… our investment in science and technology."

- **Sustaining U.S. Global Leadership: Priorities for the 21st Century Defense, Jan 2012**


SUSTAINING U.S. GLOBAL LEADERSHIP:

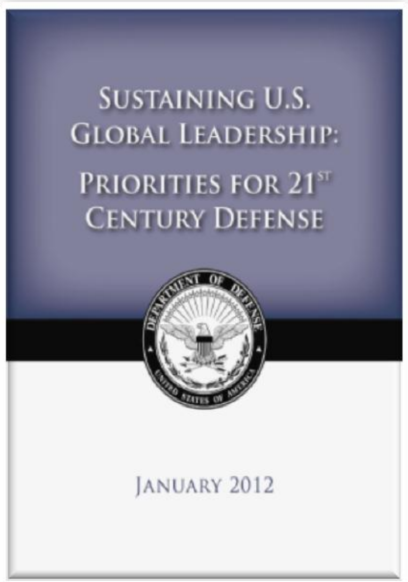
PRIORITIES FOR 21ST CENTURY DEFENSE

JANUARY 2012

- **Primary Missions of the U.S. Armed Forces**
  - Counter Terrorism and Irregular Warfare
  - Deter and Defeat Aggression
  - Project Power Despite Anti-Access/Area Denial Challenges
  - Counter Weapons of Mass Destruction
  - Operate Effectively in Cyberspace and Space
  - Defense the Homeland and Provide Support to Civil Authorities
  - Provide a Stabilizing Presence
  - Conduct Stability and Counterinsurgency Operations
  - Conduct Humanitarian, Disaster Relief, and Other Operations
  - Maintain a Safe, Secure, and Effective Nuclear Deterrent

Two new Missions

Priorities for 21st Century Defense



Two new Missions

Primary Missions of the U.S. Armed Forces

- *Defend the Homeland and Provide Support to Civil Authorities*
- *Counter Terrorism and Irregular Warfare*
- *Conduct Stability and Counterinsurgency Operations*
- *Provide a Stabilizing Presence*
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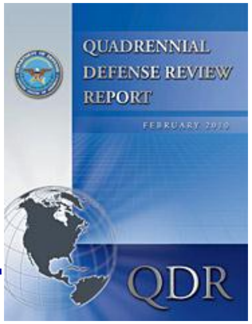
QDR 2010 Key Mission Areas

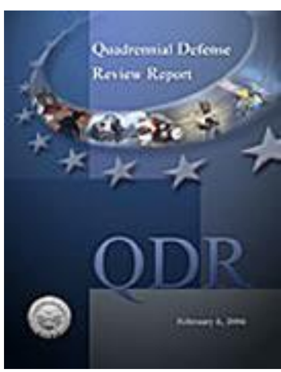


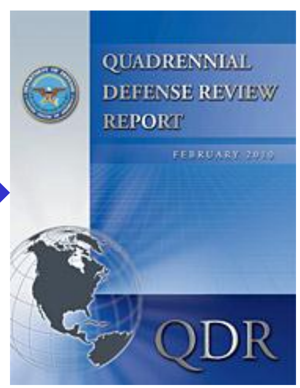
- *Defend the United States and Support Civil Authorities at Home*
- *Succeed in Counterinsurgency, Stability, and Counterterrorism Operations*
- *Build the Security Capacity of Partner States*
- *Deter and Defeat Aggression in Anti-Access Environments*
- *Prevent Proliferation and Counter Weapons of Mass Destruction*
- *Operate Effectively in Cyberspace*

QDR 2006 vs. QDR 2010

QDR 2006 Strategic Outcomes

1. ***Defend the Homeland in Depth***
2. ***Defeat Terrorist Networks***
3. ***Shape the Choices of Countries at Strategic Crossroads***
4. ***Prevent the Acquisition or use of Weapons of Mass Destruction***





QDR 2010 Mission Areas

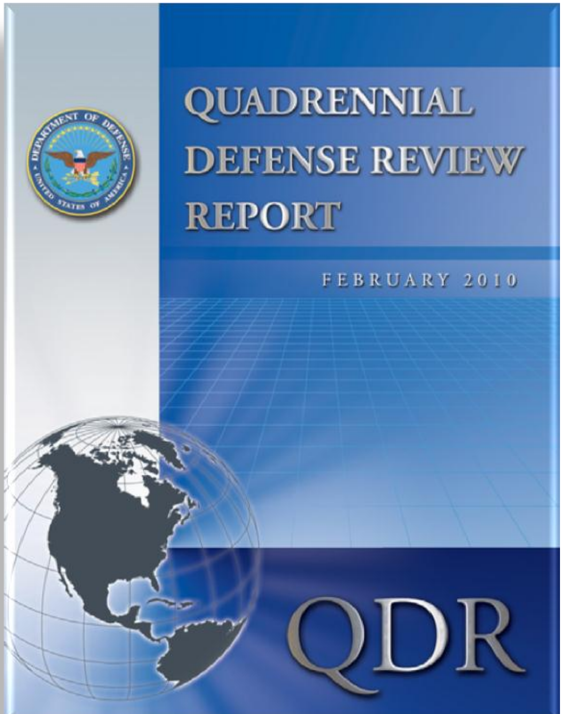
1. ***Defend the United States and Support Civil Authorities at Home***
2. ***Succeed in Counterinsurgency, Stability, and Counterterrorism Operations***
3. ***Build the Security Capacity of Partner States***
4. ***Prevent Proliferation and Counter Weapons of Mass Destruction***
5. ***Deter and Defeat Aggression in Anti Access Environments***
6. ***Operate Effectively in Cyberspace***

Two new Missions

QDR 2010 Builds on QDR 2006

- Anti-Access and Cyberspace are New -

QDR Key Mission Areas and Department Planning and Programming Guidance (DPPG) Tasking

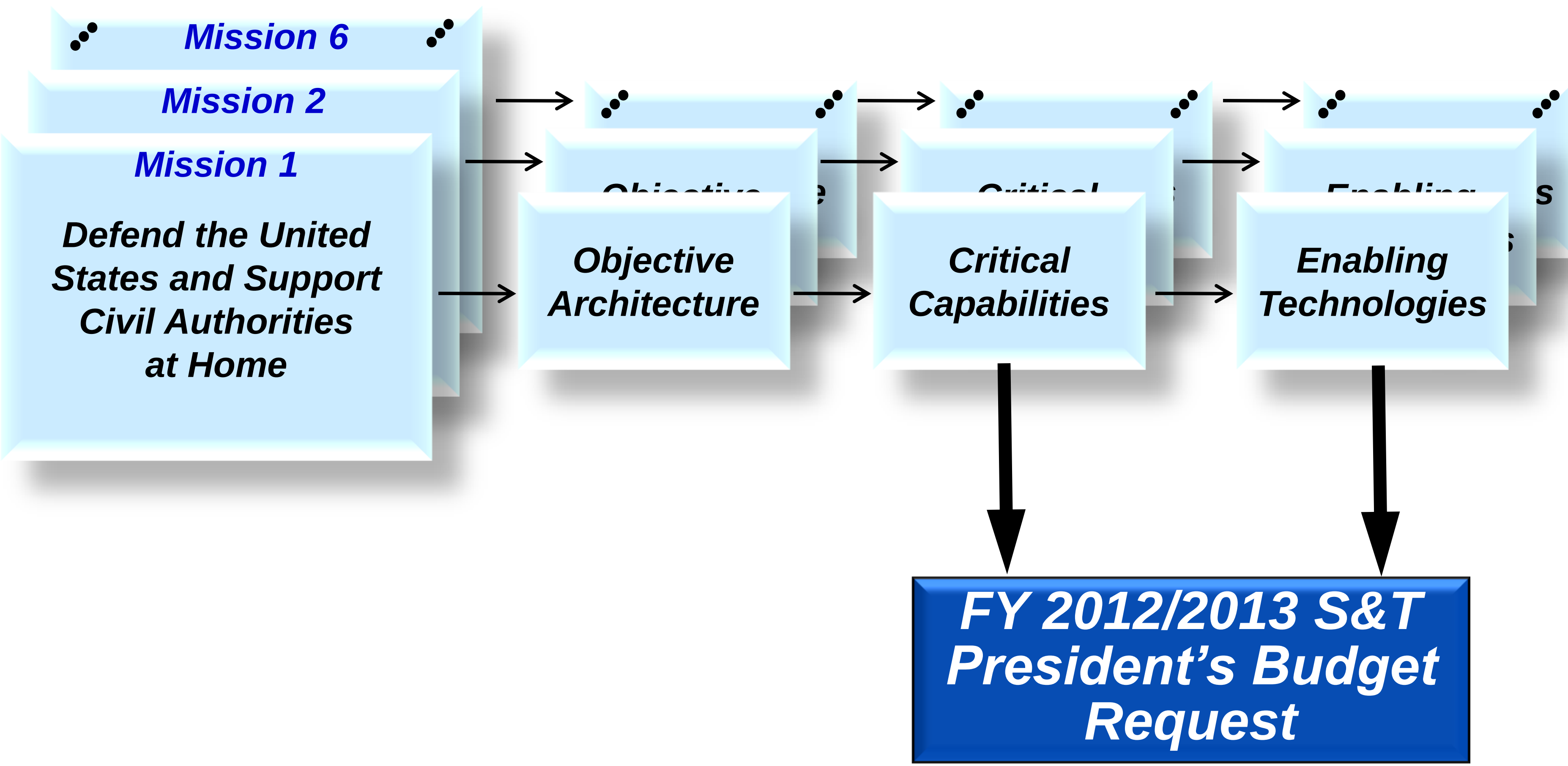


Key Mission Areas
Defend U.S. and Support Civil Authorities at Home
Succeed in COIN/Stability/CT Ops
Build Partner Security Capacity
Deter and Defeat Aggression in Anti-Access Environments
Prevent Proliferation and Counter WMD
Operate Effectively in Cyberspace

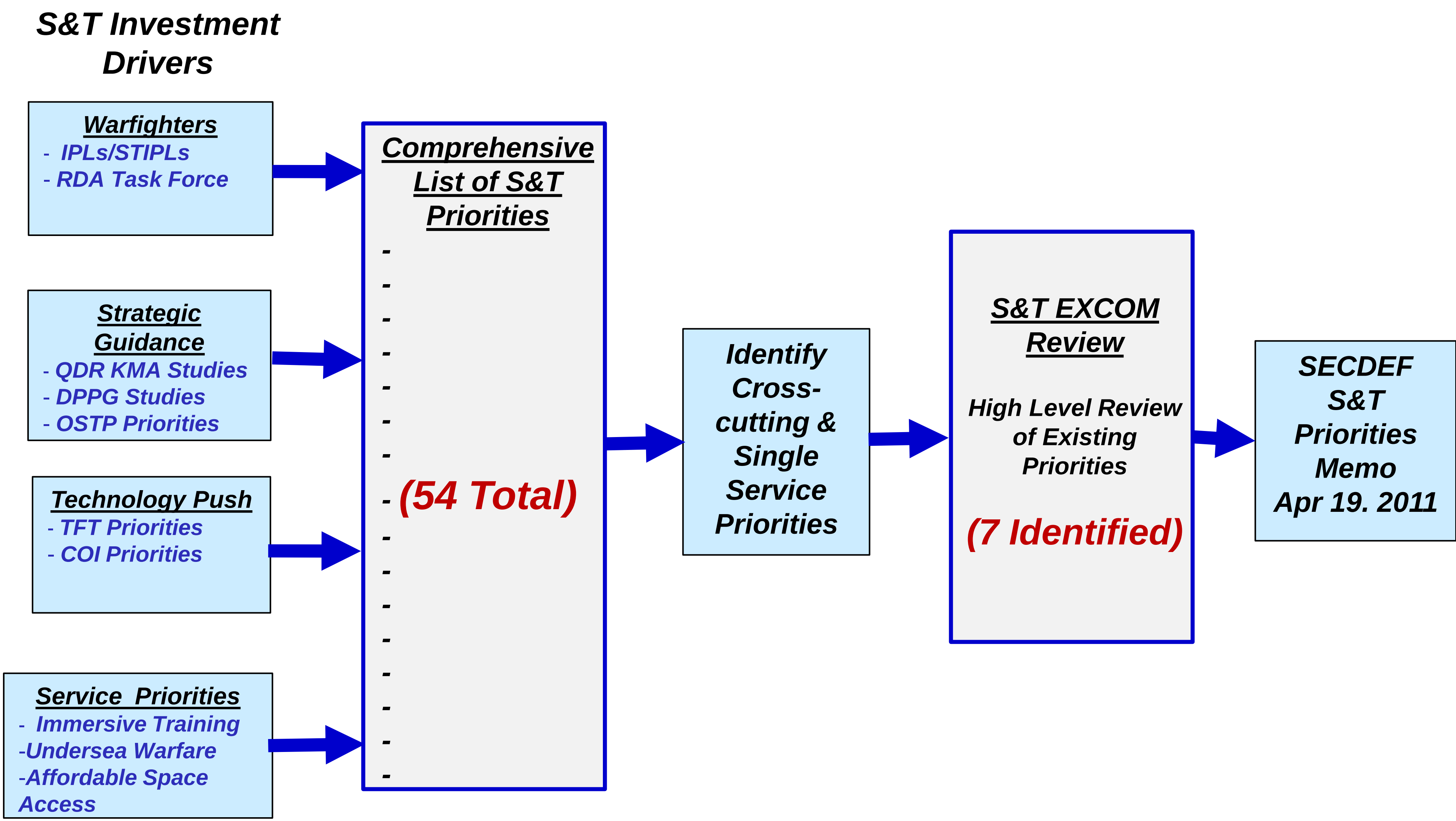
DPPG Task: *"The DDR&E, with the support of the Secretaries of the Military Departments, Directors of the Defense Agencies, and CJCS will lead an effort across the Department to identify the core capabilities and enabling technologies for each of the six QDR key mission areas."*

-- July 12, 2010 --

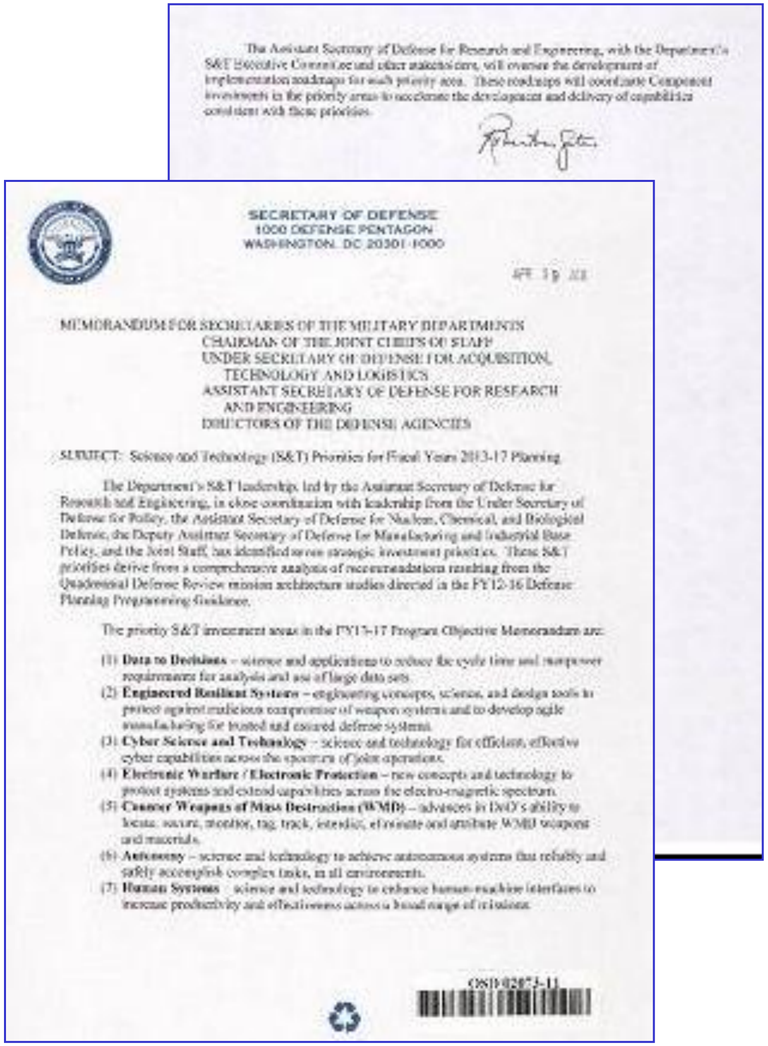
QDR KMA Study Approach



Process for Developing S&T Priorities



Secretary of Defense
S&T Priorities Memo – Apr 19, 2011



SECRETARY OF DEFENSE
1000 DEFENSE PENTAGON
WASHINGTON, DC 20301-1000

APR 19 2011

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS
CHAIRMAN OF THE JOINT CHIEFS OF STAFF
UNDER SECRETARY OF DEFENSE FOR ACQUISITION, TECHNOLOGY AND LOGISTICS
ASSISTANT SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING
DIRECTORS OF THE DEFENSE AGENCIES

SUBJECT: Science and Technology (S&T) Priorities for Fiscal Years 2013-17 Planning

The Department's S&T leadership, led by the Assistant Secretary of Defense for Research and Engineering, in close coordination with leadership from the Under Secretary of Defense for Policy, the Assistant Secretary of Defense for Nuclear, Chemical, and Biological Defense, the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy, and the Joint Staff, has identified seven strategic investment priorities. These S&T priorities derive from a comprehensive analysis of recommendations resulting from the Quadrennial Defense Review mission architecture studies directed in the FY12-16 Defense Planning Programming Guidance.

The priority S&T investment areas in the FY13-17 Program Objective Memorandum are:

(1) **Data to Decisions** – science and applications to reduce the cycle time and manpower requirements for analysis and use of large data sets.
(2) **Engineered Resilient Systems** – engineering concepts, science, and design tools to protect against malicious compromise of weapon systems and to develop agile manufacturing for trusted and assured defense systems.
(3) **Cyber Science and Technology** – science and technology for efficient, effective cyber capabilities across the spectrum of joint operations.
(4) **Electronic Warfare / Electronic Protection** – new concepts and technology to protect systems and extend capabilities across the electro-magnetic spectrum.
(5) **Counter Weapons of Mass Destruction (WMD)** – advances in DoD's ability to locate, secure, monitor, tag, track, interdict, eliminate and attribute WMD weapons and materials.
(6) **Autonomy** – science and technology to achieve autonomous systems that reliably and safely accomplish complex tasks, in all environments.
(7) **Human Systems** – science and technology to enhance human-machine interfaces to increase productivity and effectiveness across a broad range of missions.

OSD 02073-11

The Assistant Secretary of Defense for Research and Engineering, with the Department's S&T Executive Committee and other stakeholders, will oversee the development of implementation roadmaps for each priority area. These roadmaps will coordinate Component investments in the priority areas to accelerate the development and delivery of capabilities consistent with these priorities.

S&T Priorities

- *Data-to-Decisions*
- *Engineered Resilient Systems*
- *Cyber Science and Technology*
- *Electronic Warfare / Electronic Protection*
- *Counter Weapons of Mass Destruction*
- *Autonomy*
- *Human Systems*

"The Assistant Secretary of Defense for Research and Engineering, with the Department's S&T Executive Committee and other stakeholders, will oversee the development of implementation roadmaps for each priority. These roadmaps will coordinate Component investments in the priority areas to accelerate the development and delivery of capabilities consistent with these priorities."

Priority S&T Investment Areas for FY 2013-2017

- **Data-to-Decisions**
  - Science and applications to reduce the cycle time and manpower requirements for analyses and use of large data sets.
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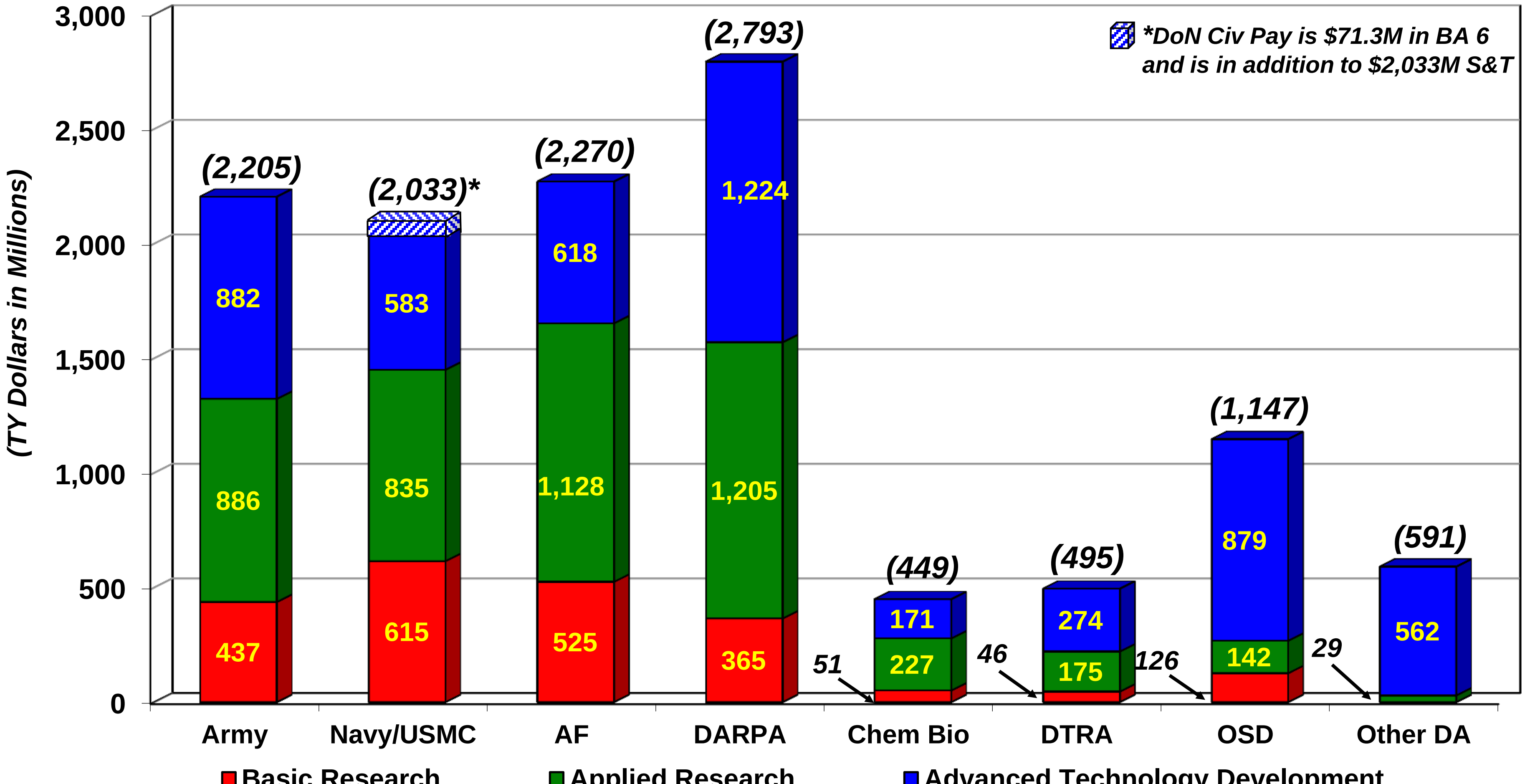
Outline

- *Changes, Challenges & Priorities*
- ***FY2014 S&T President's Budget Request***

FY14 DoD S&T Budget Request

Total FY14 S&T request = $11.98B

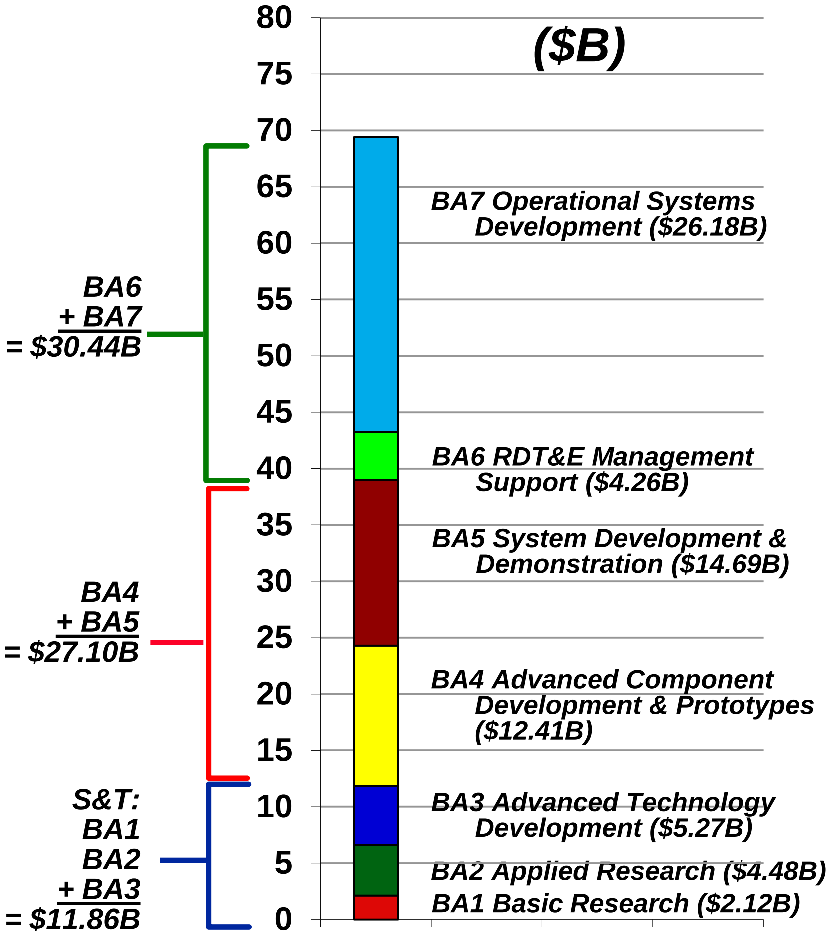


Distribution Statement A - Approved for public release. Distribution is unlimited.

FY13 and FY14 RDT&E Budget Request Comparison

- in Then Year Dollars -

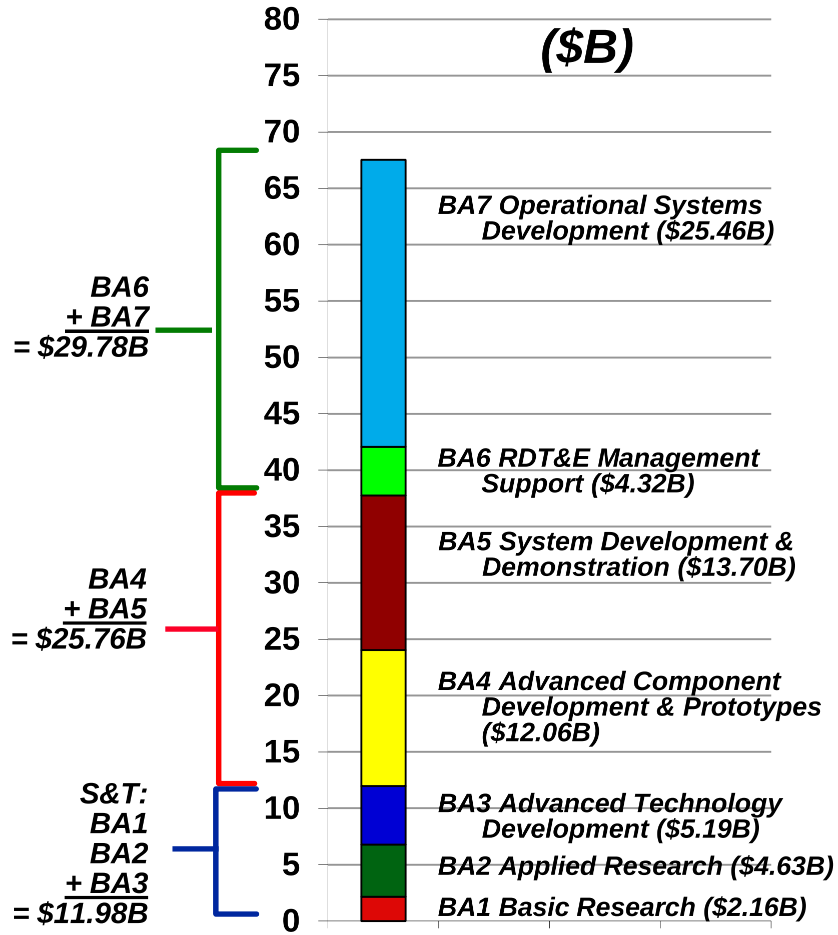
FY13 RDT&E request = $69.41B
(Budget Activities 1-7)



Technology Base (BA1 + BA2) = $6.59B

PBR13 S&T is 17.0% of RDT&E

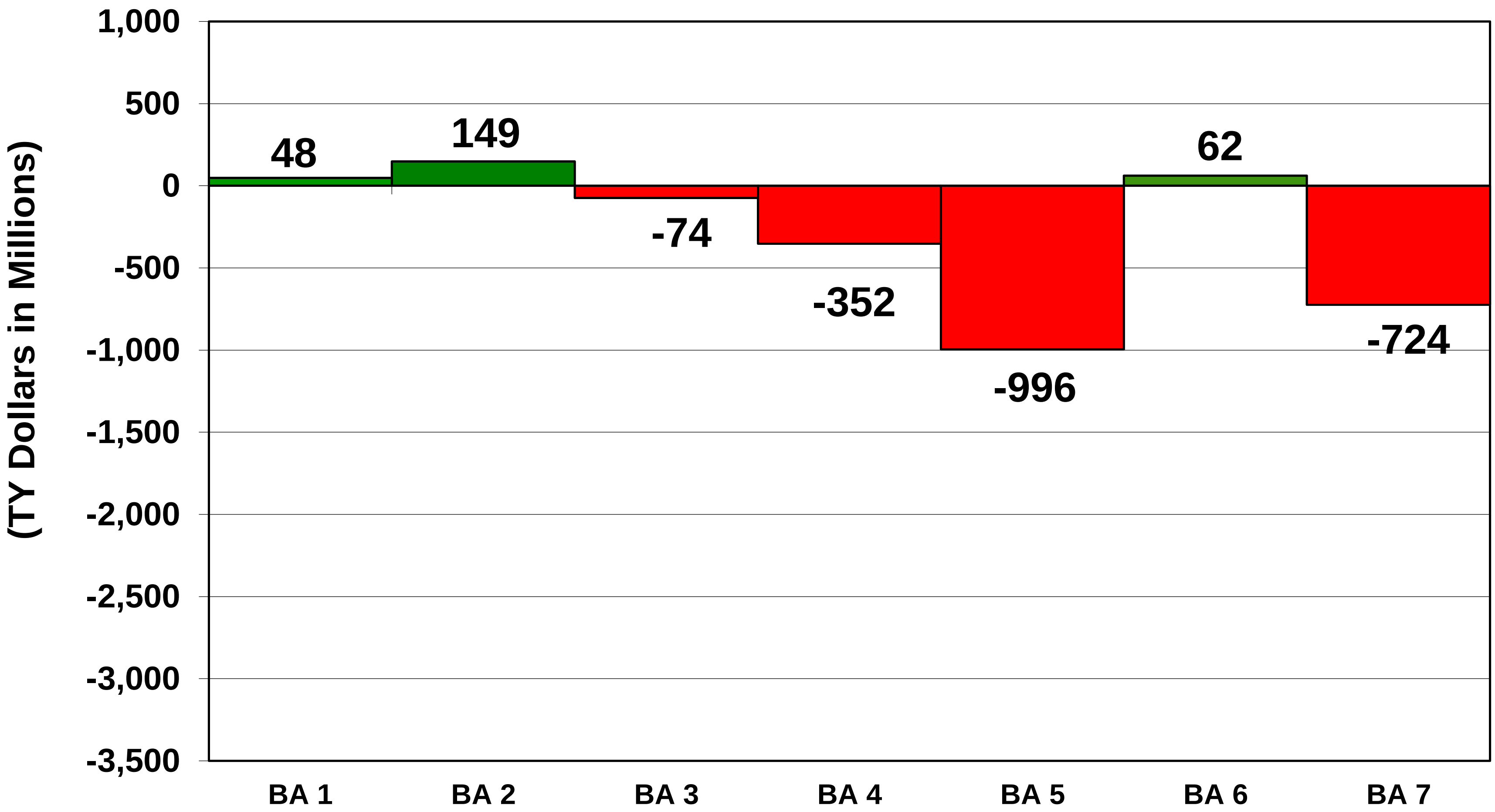
FY14 RDT&E request = $67.52B
(Budget Activities 1-7)



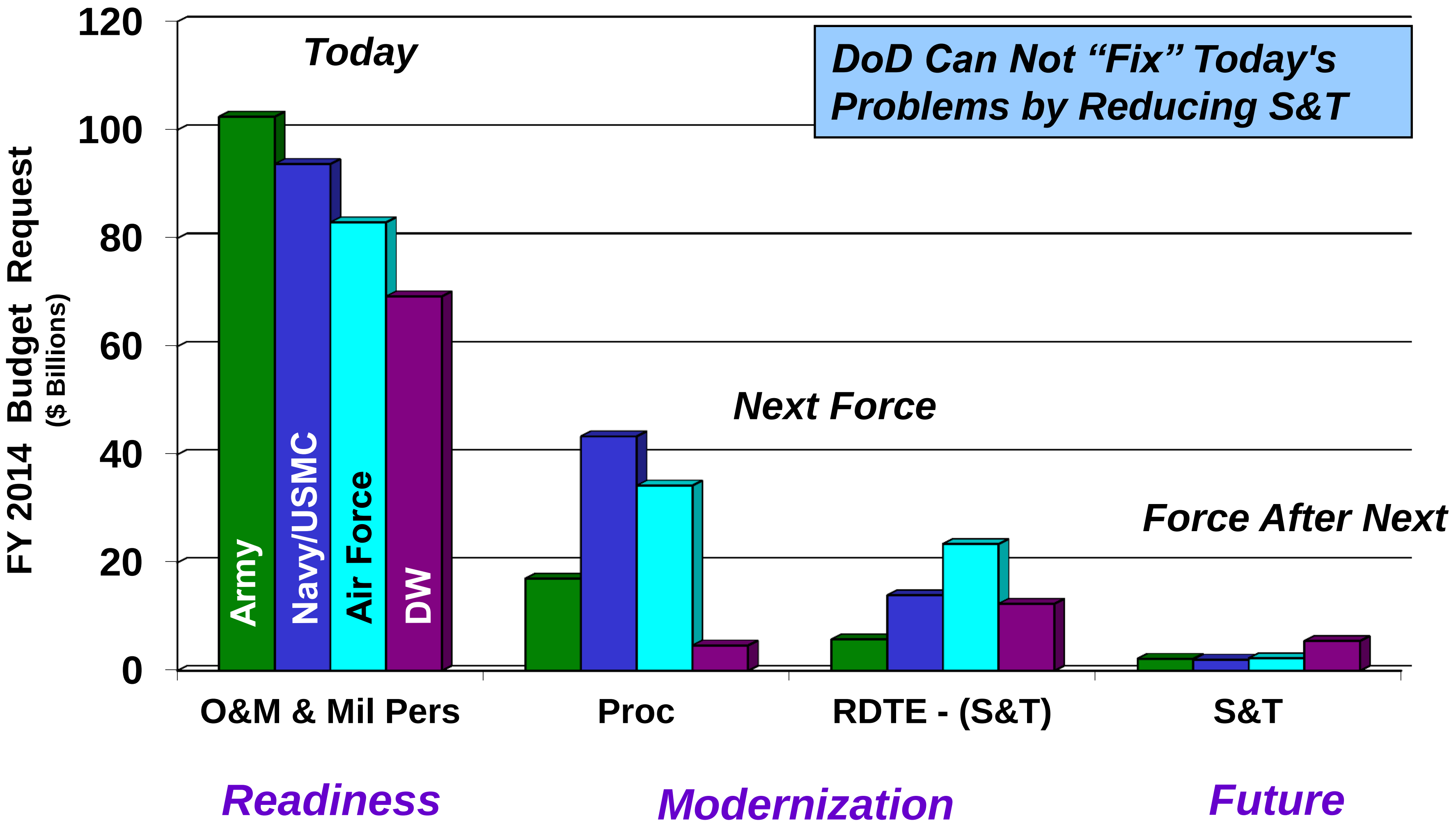
Technology Base (BA1 + BA2) = $6.79B

PBR14 S&T is 17.7% of RDT&E

RDT&E Budget Request Overview
- FY13 and FY14 Comparison -



FY14 Technology Investment Compared to Other DoD Categories



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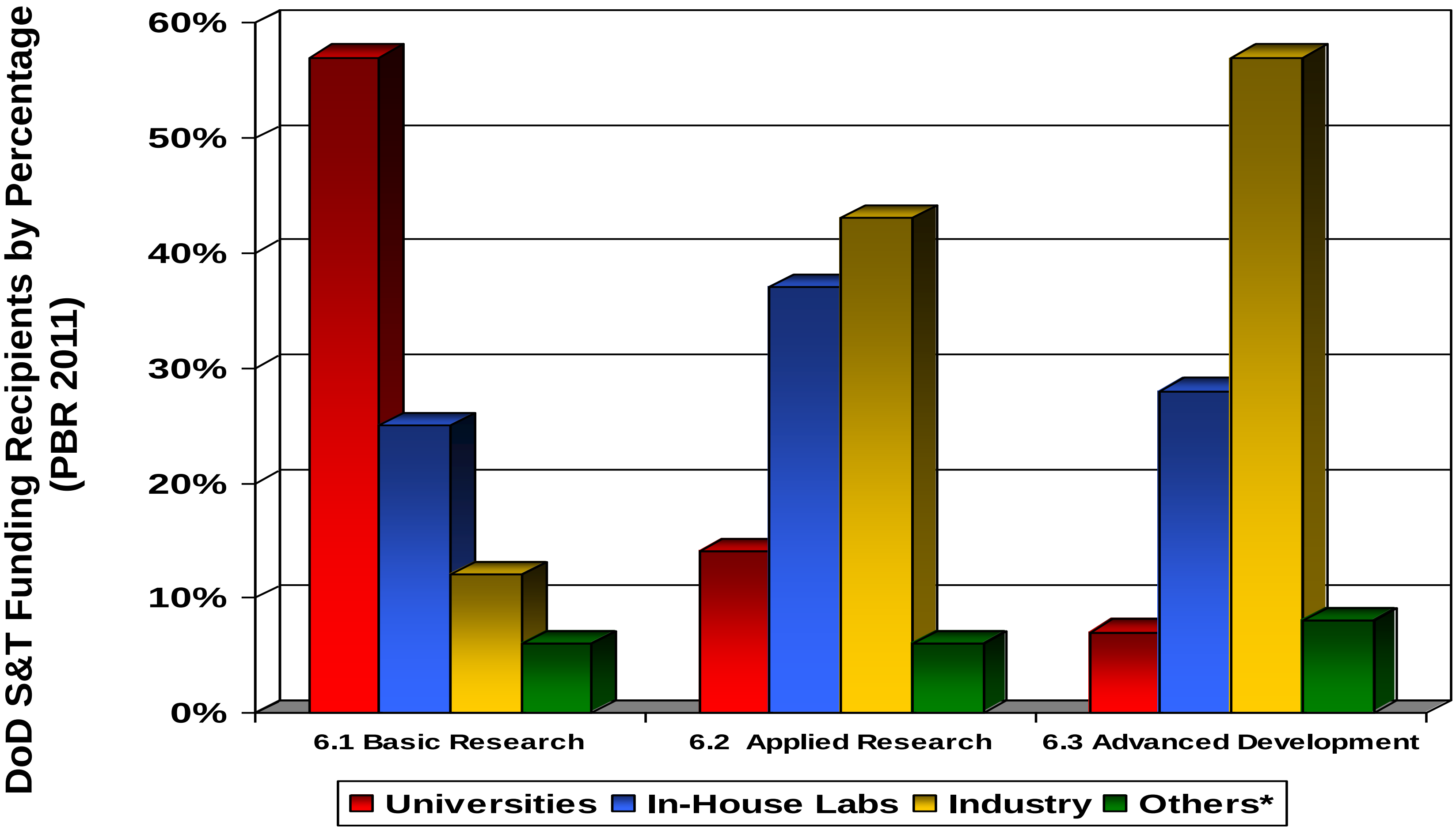
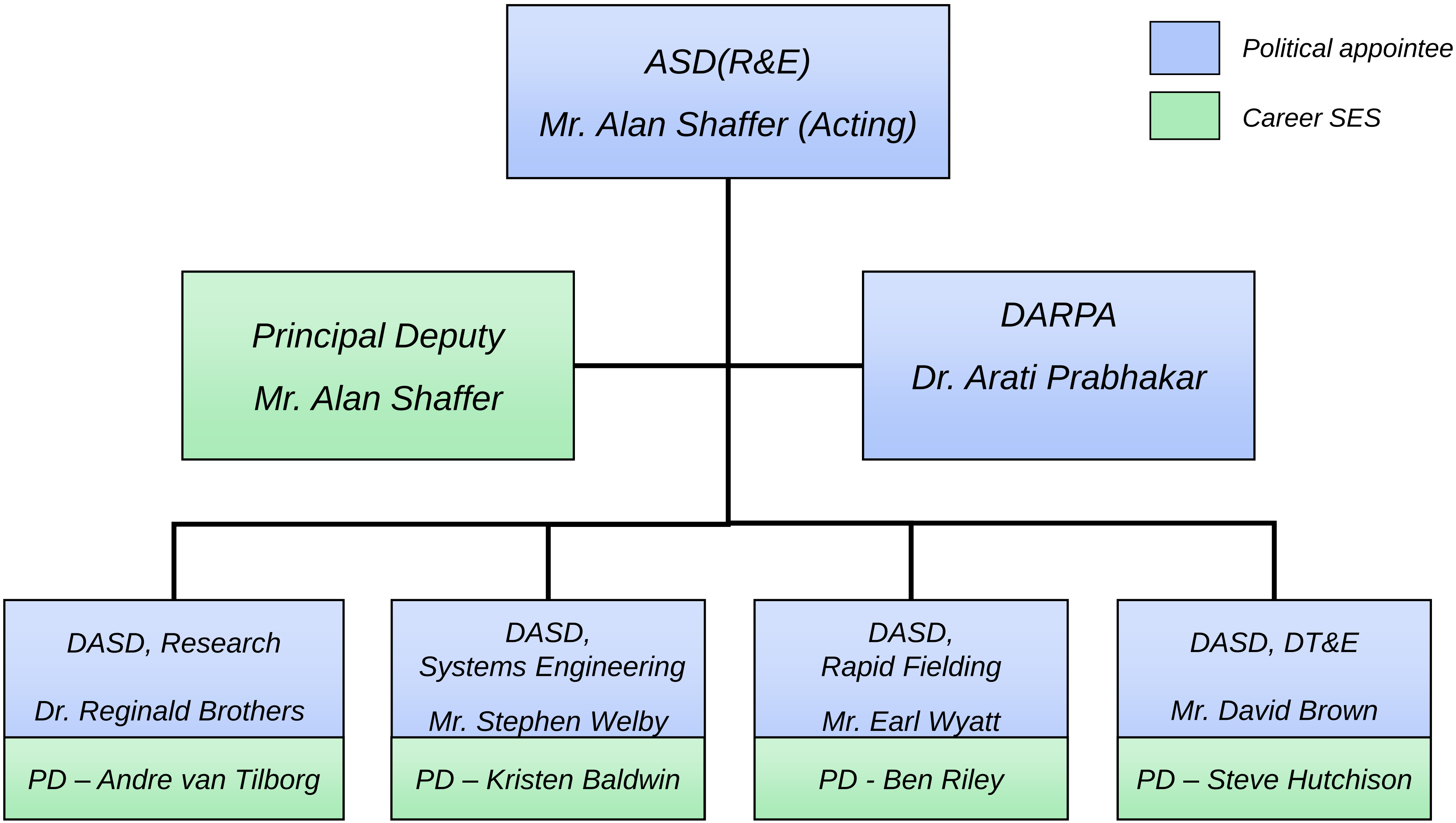
Recipients of DoD S&T Funds



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

Source: National Science Foundation Report (PBR 2011)

ASD(R&E) – Organization



Backup


DANGER
TOO MUCH THINKING CAN RESULT IN YOUR BECOMING LOST WITH SOME BIG BAD MONSTERS

Basic Research Areas

- Six Disruptive Basic Research Areas
  - Engineered Materials (metamaterials and plasmonics)
  - Quantum Information and Control
  - Cognitive Neuroscience
  - Nanoscience and Nanoengineering
  - Synthetic Biology
  - Computational Modeling of Human and Social Behavior

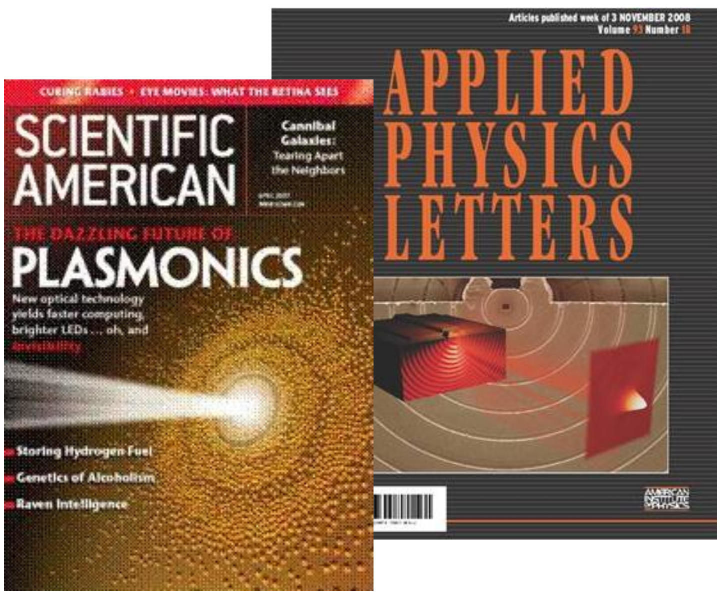
Context

- Six Science topics were identified with high potential for disruptive applications.
  - Fields of basic research undergoing significant progress, and hold the promise for continuing significant progress.
  - Areas that could have broad and likely long-range major impact on existing or future DoD missions and capabilities.
  - Judging when DoD should be a) uninterested, b) an informed observer, c) play a role in supporting this field, or d) be a major driver of select areas and research owners?
- Input from 6.1 topics and reviews, university and laboratory visits, scientific journals, National Academies reports. What scientific metrics can we identify? Who else is funding? What is the International activity vs. U.S.?

I. Metamaterials and Plasmonics

Engineered design of basic properties and transport of energy/information in materials & structures

- Enabled capabilities
  - Optics with negative index of refraction
  - Plasmon-enhanced Detectors & Imagers
  - Phased Antenna Arrays
  - Breaking the diffraction limit
  - Thermoelectrics with record efficiencies



- ***Select breakthroughs***
  - *Sub-wavelength Elements, Plasmonics, Photonic Crystals, Metamaterials*
  - *Self-sensing & Self-healing Materials*
  - *Biologically Inspired Structures*
  - *Computational & Fast-algorithm Tools*

- ***Key research challenges:***
  - *Precise control of materials on an atomic scale*
  - *Efficiently convert optical radiation into localized energy, and vice versa.*
  - *Enhancing local photophysical processes*
  - *Integrating plasmonics with nanostructured semiconductor devices*

II. Quantum Information and Control

Manipulate and control nature down to the precision of a single quantum.

- Enabled capabilities
  - **Quantum communication:** practical ultra-secure communication
  - **Quantum simulation:** developing new classes of materials for new applications
  - **Quantum sensing, metrology and imaging:** sensitivity/precision/resolution beyond best possible with classical means
  - **Quantum computing:** code breaking, optimized logistics, data base searches
- Key research challenges
  - Maintaining quantum coherence over time
  - Discovering new algorithms that fully exploit QIS for additional new capabilities
  - New techniques to control quantum systems
  - New materials, fabrication for long coherence time

Polynomial-Time Algorithms for Prime Factorization and Discrete Logarithms on a Quantum Computer*

Peter W. Shor†

Abstract

A digital computer is generally believed to be an efficient universal computing device; that is, it is believed able to simulate any physical computing device with an increase in computation time by at most a polynomial factor. This may not be true when quantum mechanics is taken into consideration. This paper considers factoring integers and finding discrete logarithms, two problems which are generally thought to be hard on a classical computer and which have been used as the basis of several proposed cryptosystems. Efficient randomized algorithms are given for these two problems on a hypothetical quantum computer. These algorithms take a number of steps polynomial in the input size, e.g., the number of digits of the integer to be factored.

Keywords: algorithmic number theory, prime factorization, discrete logarithms, Church's thesis, quantum computers, foundations of quantum mechanics, spin systems, Fourier transforms

AMS subject classifications: 81P10, 11Y05, 68Q10, 03D10

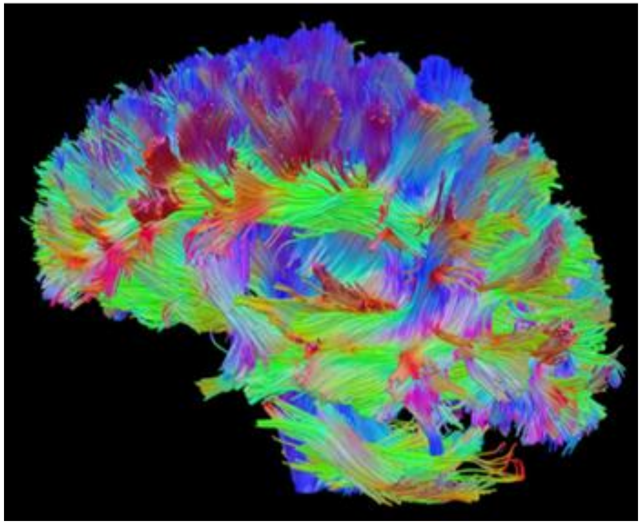
Select breakthroughs

- ***Quantum factorization algorithm*** *(Shor 1995): solve intractable problems*
- ***Quantum gas microscope*** *(Greiner 2010): observation of an ensemble of atoms in a lattice with down to a single atom resolution*

III. Cognitive Neuroscience

More deeply understand and more fully exploit the fundamental mechanisms of the brain.

- Enabled capabilities
  - Deeper understanding of human information processing, learning and decision making
  - Direct mental control of engineered systems
  - Better design of information displays and system controls
  - Compensation for performance under stress
  - Ameliorate/ prevent PTSD and TBI
- Select breakthroughs
  - Advances in brain imaging; e.g. fMRI, Diffusion Tensor Imaging, and digital EEG.
  - Advances in correlation of brain-structure to function
  - Massively parallel computation enabling brain signal analysis



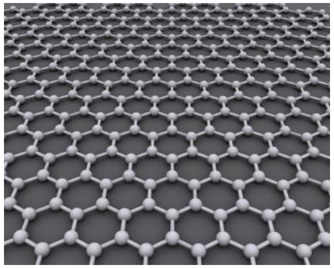
Map of brain interconnectivity as measured by Diffusion Tensor Imaging (DTI)

- ***Key research challenges***
  - *Solving the inverse problem of predicting human behavior from brain signals*
  - *Translating clinical measurements & analyses to uninjured personnel*
  - *Developing models incorporating individual brain variability*

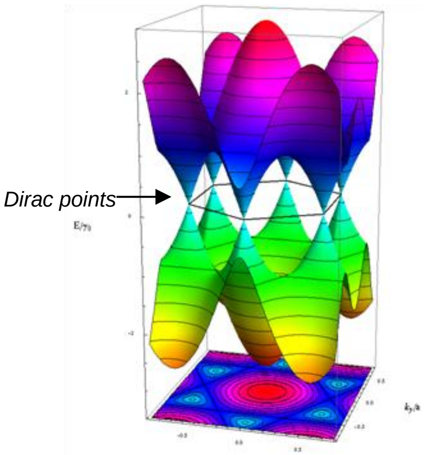
IV. Nanoscience and Nanotechnology

Discover and exploit unique phenomena at nanometer dimensions

- Enabled capabilities
  - Electronics & Sensing: ultra-fast electronics, ubiquitous embedded sensors, curvilinear electronics, ultra-low voltage devices
  - Lightweight armor, high-strength nano-coatings
  - Power and Energy: Fuel-cells, portable electronics, mobile power, thermoelectrics
- Select breakthroughs
  - Nano-particle coating & functionalization
  - Catalysts for energy-harvesting
  - Graphene and carbon nanotubes (Nobel Prize)
- Key research challenges
  - Low-defect density graphene; single chirality nanotubes
  - Nano-manufacturing using designed molecular assemblies



Graphene monolayer



Graphene Bandstructure with Dirac points

V. Synthetic Biology

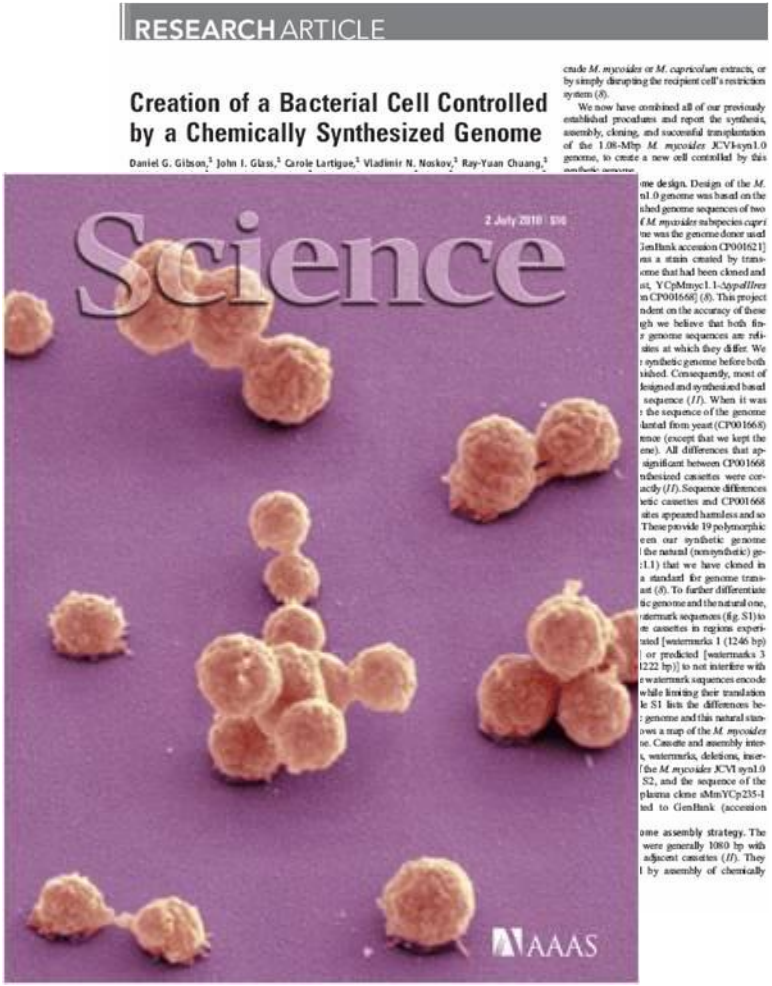
The promise of engineered biology for a multitude of applications.

Enabled capabilities

- Bio-production including bio-fuels
- Bio-sensors
- Tissue regeneration
- New and faster ways to produce vaccines
- Algae-based food production
- Clean water as a bio-based capability

Key research challenges:

- *Modeling and simulation to address complexity of pathways*
- *Automation of trials*
- *Selection of appropriate host cell compatible with synthetic genome*
- *Regulation and societal acceptance*



VI. Computational Models of Human Behavior

A fundamental understanding and predictive capability of human behavior dynamics from individuals to societies.

- ***Enabled capabilities***
  - *Predictive models supporting strategic, operational, and tactical decision making and planning*
  - *Real time cultural situational awareness*
  - *Immersive training and mission rehearsal*
  - *Cross cultural coalition building*
- ***Key research challenges:***
  - *Conflicting theories*
  - *Data management and fusion*
  - *Mathematical complexity*
  - *Validation of models*

- ***Measures of success***
  - *Early success of simple models*
  - *Success of social network analysis*
  - *Prediction of crowd tipping points*

Priority S&T Investment Areas for FY 2013-2017

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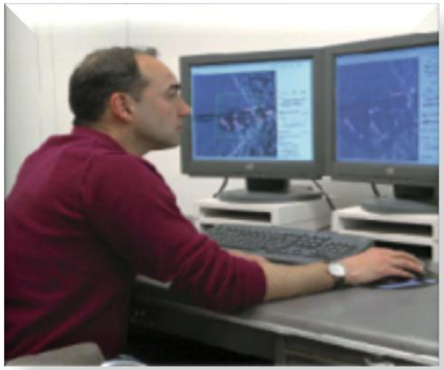
Data to Decisions – Challenges

Data Management Layer

Analytics Layer

User Interface Layer



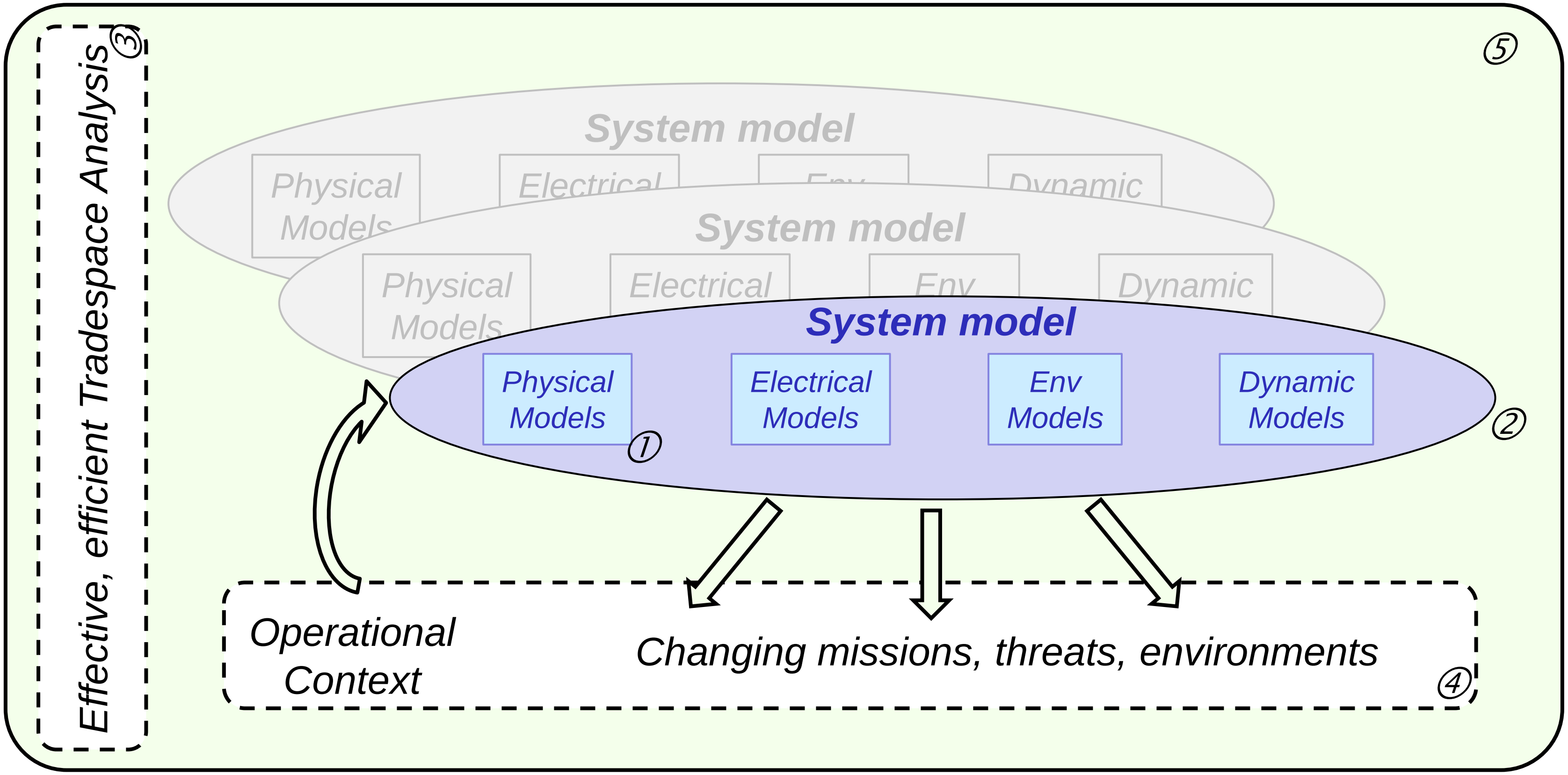
Current assessment is that unstructured data analytics is the most challenging and critical component of D2D

- *Tracking*
  - *Automated tools that support 100x improvement in the number of tracks that an analyst manages*

- *Image analysis*
  - *Automated tools that support 100x improvement in the number of objects, activities, and events that an analyst can manage*

- *Text analysis*
  - *Automated tools that improve the extraction rate of information from documents in any language with high probability of correct extraction*

Engineered Resilient Systems (ERS)



①Better models, ② effectively linked together, generating alternative systems designs informed by ③ tradespace analysis and ④ testing against variations in operational context, ⑤ enabled through a collaborative design environment

Cyber Science & Technology

Assuring Effective Missions	Assess and control the cyber situation in mission context
Agile Operations	Dynamically reshape cyber systems as conditions/goals change, to escape harm

Resilient Infrastructure	Withstand cyber attacks, and sustain or recover critical functions
Trust	Establish known degree of assurance that devices, networks, and cyber-dependent functions perform as expected, despite attack or error

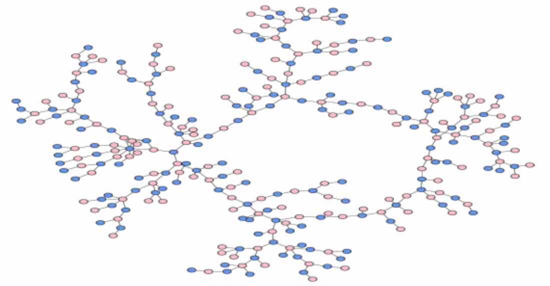
EW/EP – Technical Challenges

Electronic Warfare Technical Challenges	*Desired End State Objective Capabilities*
TC1: Cognitive, Adaptive Capabilities	*Effectively outpace adversary decision processes; deny their ability to form an accurate tactical picture*
TC2: Coordinated / Distributed / Network-Enabled Systems	***Spatially and temporally diverse responsiveness*** *to dense and complex threat environments; ensure blue force interoperability*
TC3: Preemptive / Proactive Effects	***Real-time active/passive sensing*** *of "silent" threats; continuously monitor threat response to* ***assess and optimize EA effectiveness***
TC4: Broadband / Multispectral Systems	*Assured ability to* ***sense and respond to any signal or threat*** *and eliminate "blind spots" in our control of the EMS*
TC5: Modular / Open / Software-Configurable Architectures	*Timely deployment of advanced capabilities to counter rapidly evolving threats and respond to technology surprise*
TC6: Advanced Electronic Protection Techniques and Technology	***Protect ISRT sensors from hostile EA; allow unfettered operation in the increasingly dense EM environment***

Counter WMD – Challenges

- ***Next gen rad detection, e.g. nanomaterials; ionized air; HSI***
- **Alternate signatures related to weapon activity**
  - *People, programs, communications, facilities, behaviors…*
- ***Persistent intelligence, surveillance and reconnaissance***
  - *Sensor development and platform integration*
  - *Technical, intelligence and social data fusion*

- ***Data-to-Decision Tools***
  - *Next-generation reachback and information sciences capabilities*
  - *High performance computing*
- ***Architectures for prompt access and low latency***
- ***Beyond physics***
  - *Human behavior and intent detection*
  - *Social network analysis*



Autonomy—Technical Challenges

Working definition of "Autonomy": Having the capability and freedom to self-direct.

An autonomous system makes choices and has the human's proxy for those decisions.

The balance between human and system decision making is defined by policy and operational requirements.

1. ***Machine Reasoning and Intelligence***
2. ***Human/Autonomous System Interaction and Collaboration***
3. ***Scalable Teaming of Autonomous Systems***
4. ***Testing and Evaluation (T&E) and Verification and Validation (V&V)***

All address Two Sources of Uncertainty/Brittleness:

1. ***Dynamic and Complex Mission Requirements***
2. ***Dynamic and Complex Operational Environments***

Overarching Problem Statement:

In a static environment, with a static mission, automation and autonomy converge. However, in reality, where dynamic environments collide with dynamic missions, automation can only support a small fraction of mission requirements.

Human Systems
Training Technical Challenges

Challenge 1: First Principles for Training Design

- Synthetic environments for experimentation and learning
- Validated tools to optimize training outcomes across individuals and teams

Challenge 2: Realistic, Adaptive and Interactive Scenario Based Training

- Persistent integration of real world events and content into scenarios and syllabi
- Training that adapts to individual needs of warfighters in near real-time

Challenge 3: Persistent, Affordable, Integrated Training

- Mission-focused training simulations that support individual and collective training
- Seamless, secure integration of training systems across services and coalition partners

Human Systems Interface Challenges

Challenge 1: Human-Machine Teaming

- Robots that can participate in realistic dialogue with the operator
- Domain-agnostic performance metrics for human-machine interactions

Challenge 2: Intelligent, Adaptive Aiding

- Adaptive determination of relevant data for human-machine interaction
- Platform-independent frameworks to capture cognitive concepts of rich user models: beliefs, desires, intentions, obligations, and goals

Challenge 3: Intuitive Interaction

- High fidelity operator state modeling with information from rich user models
- Coordinated command and control of hybrid forces

Virtual lab

Actual lab

Terms of Reference for the Defense Science & Technology Senior National Representatives of the United States and the Kingdom of Sweden

Mr. Bob Baker

Deputy Director, Plans & Programs

Acting, Assistant Secretary of Defense

For Research and Engineering

Purpose

- **Promote the exchange of information under existing agreements and Memoranda of Understanding in all matters related to Defense Research**
- **Senior National Representatives**
  - **Mr. Jan-Olof Lind, Director General, Swedish Defense Research Agency (FOI)**
  - **Mr. Alan R. Shaffer, Assistant Secretary of Defense, Research & Engineering**

Signed 28 February 2013

Senior National Representatives will endeavor to:

- Review respective science and technology programs
- Provide high-level support for current and future cooperative efforts
- Identify new technical areas and specific opportunities in which information exchange may be desired
- Review existing U.S. - Sweden Data Exchange Agreements, and existing U.S. - Sweden cooperative research and development agreements, MOUs, and other arrangements to identify further technical areas in which the exchange of information may be beneficial
- Promote the exchange of scientists and engineers between U.S. DoD and Sweden, subject to existing U.S. DoD-Sweden agreements covering such exchanges

Senior National Representatives will endeavor to:

- Meet formally at least once every other calendar year, with the meeting held alternately in the United States and Sweden
- to coordinate on a report summarizing U.S. DoD-Sweden cooperative activities

Terms of Reference will remain in effect for 5 years and may be extended with the consent of the SNRs