# DoD Basic Research Program with a Focus on Academia

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# Key Challenges and Trends


the **JOE** 2010
**JOINT OPERATING ENVIRONMENT**

UNITED STATES JOINT FORCES COMMAND
USJFCOM

READY FOR TODAY. PREPARING FOR TOMORROW.
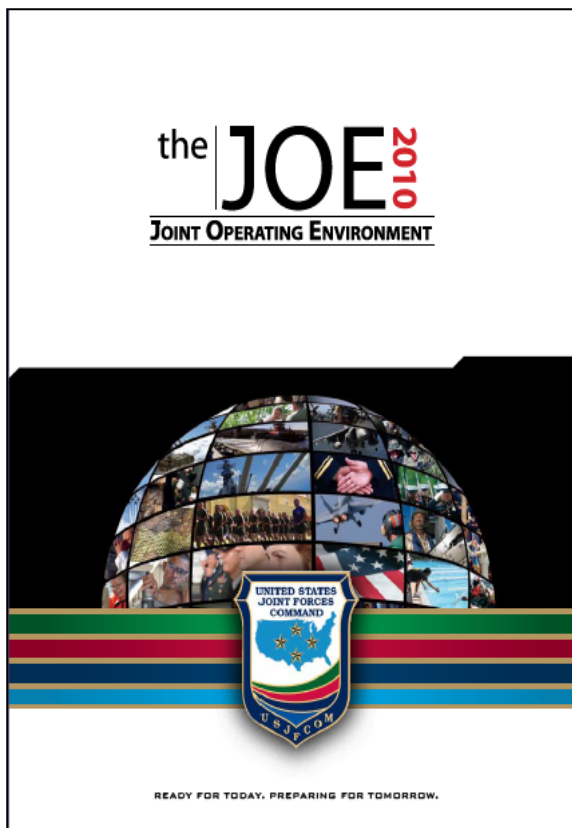
- **Demographics**
  - Aging population in developed world
  - Growing youth population in developing world

- **Globalization**
  - World wide access to knowledge

- **Economics**
  - New wealth in Brazil, Russia, India & China
  - Large debts and deficits in developed nations

- **Energy**
  - High on every nation's priority list

- **Climate change & natural disasters**

- **Challenges to existing state structures**
  - Radical ideologies
  - Internet communities

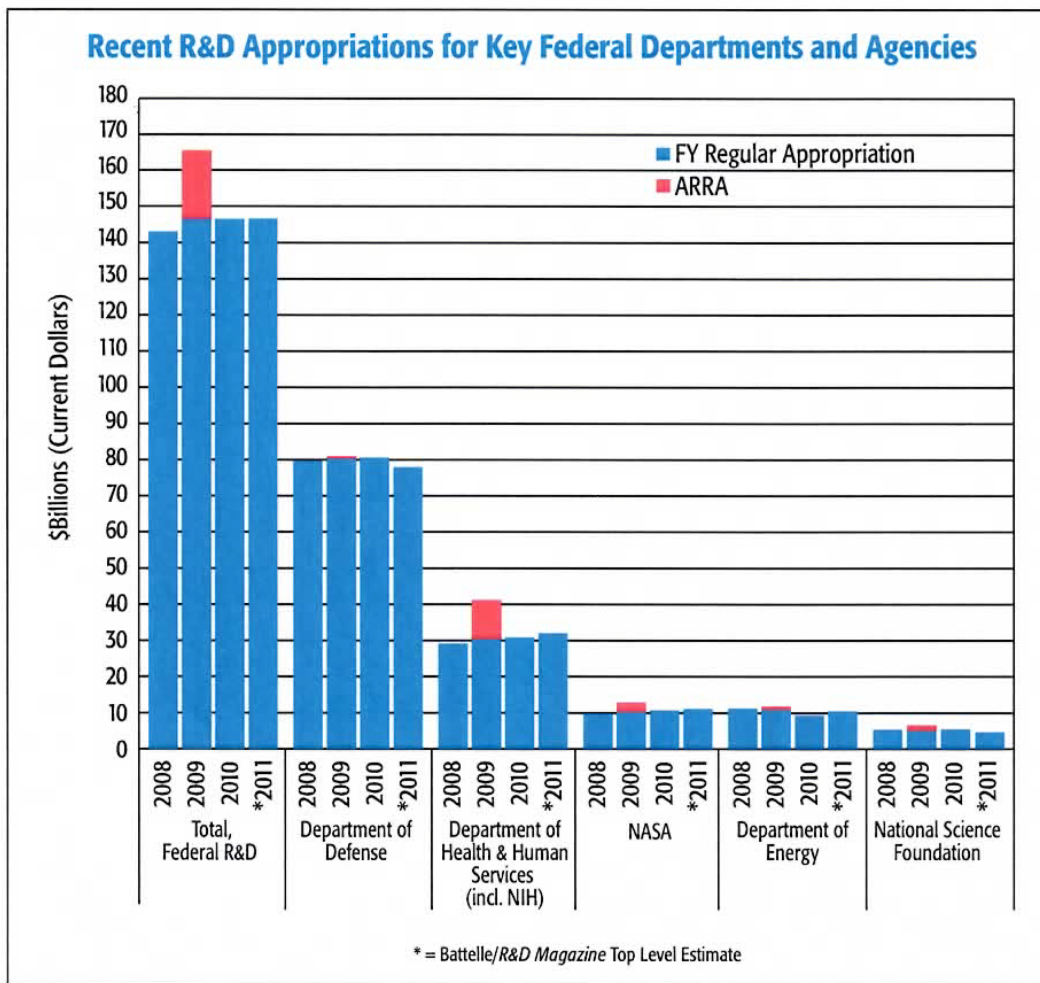> **A robust S&T program is necessary to address today's complex and changing defense environment**

# Outline

- **Introduction**

- **By the numbers**

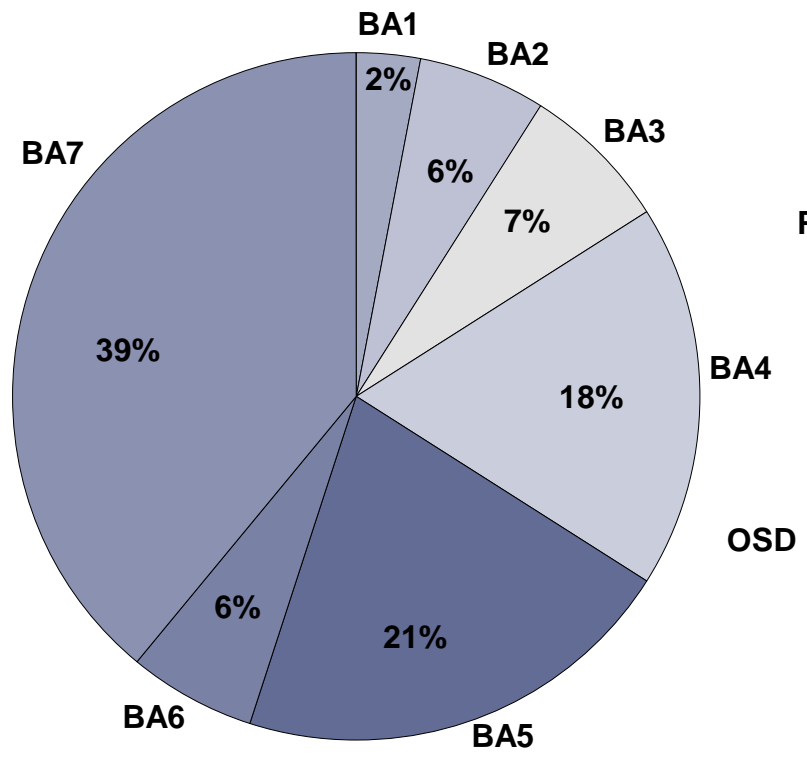- **Science initiatives**

- **Summary**

# Federal Research Spending



**Recent R&D Appropriations for Key Federal Departments and Agencies**

Y-axis: $Billions (Current Dollars), 0 to 180

Legend:
- FY Regular Appropriation
- ARRA

Categories (years 2008, 2009, 2010, *2011):
- Total, Federal R&D
- Department of Defense
- Department of Health & Human Services (incl. NIH)
- NASA
- Department of Energy
- National Science Foundation

* = Battelle/*R&D Magazine* Top Level Estimate

Source: Battelle/*R&D Magazine* with data from OSTP, AAAS

# Basic Research Portfolios



- **Defense Investments**
- **Defense Recipients**
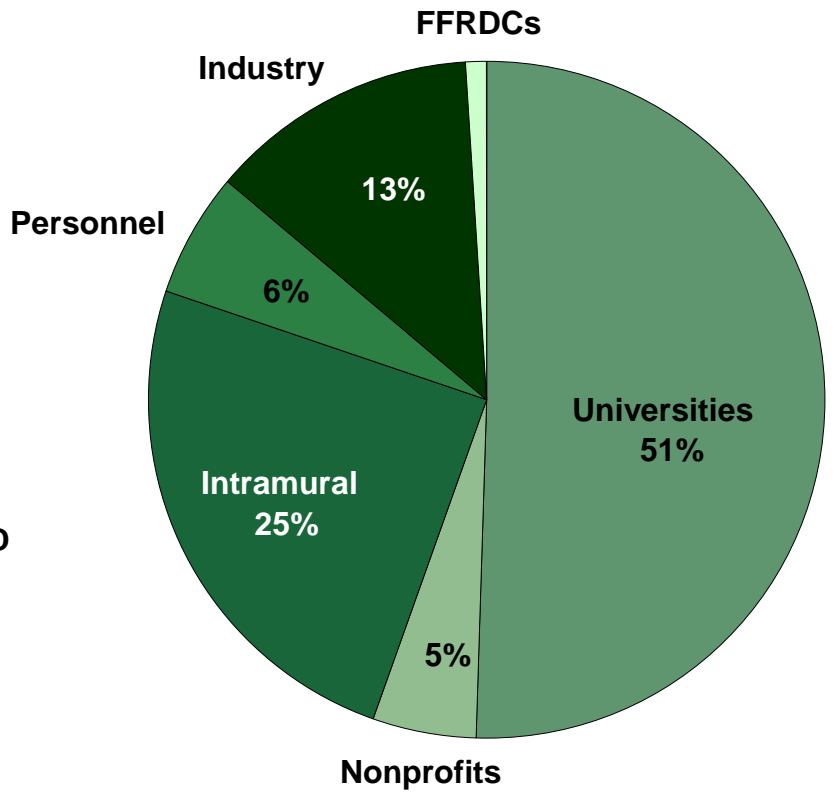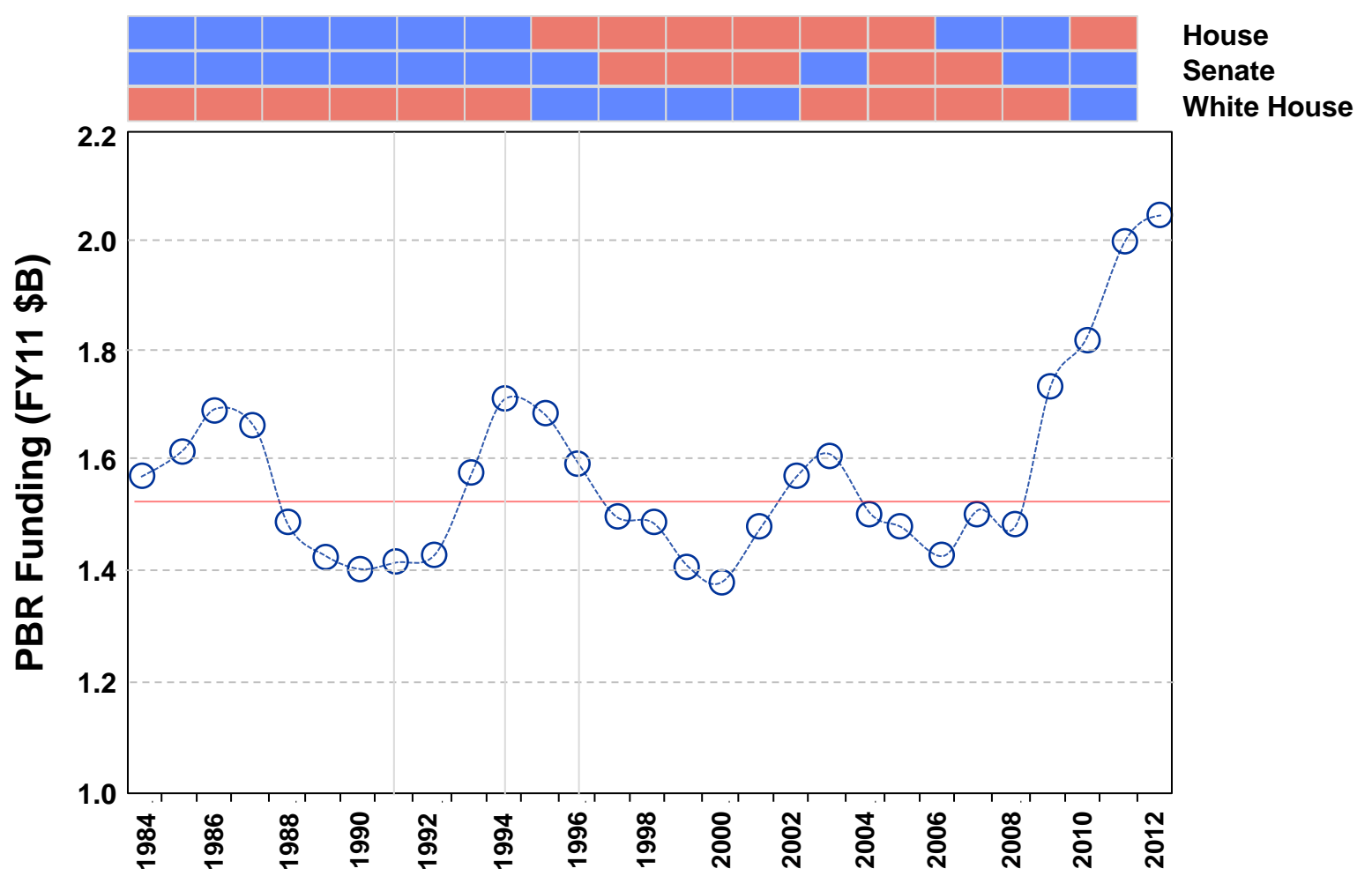
Defense Investments pie chart:
- BA1: 2%
- BA2: 6%
- BA3: 7%
- BA4: 18%
- BA5: 21%
- BA6: 6%
- BA7: 39%
- OSD

Defense Recipients pie chart:
- FFRDCs
- Industry: 13%
- Personnel: 6%
- Intramural: 25%
- Nonprofits: 5%
- Universities: 51%

**Distribution Statement A: Approved for public release, distribution is unlimited**

# Basic Research Funding

**Distribution Statement A: Approved for public release, distribution is unlimited**

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- **By the numbers**

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- **Summary**

A lesson in research from Ted Hänsch…
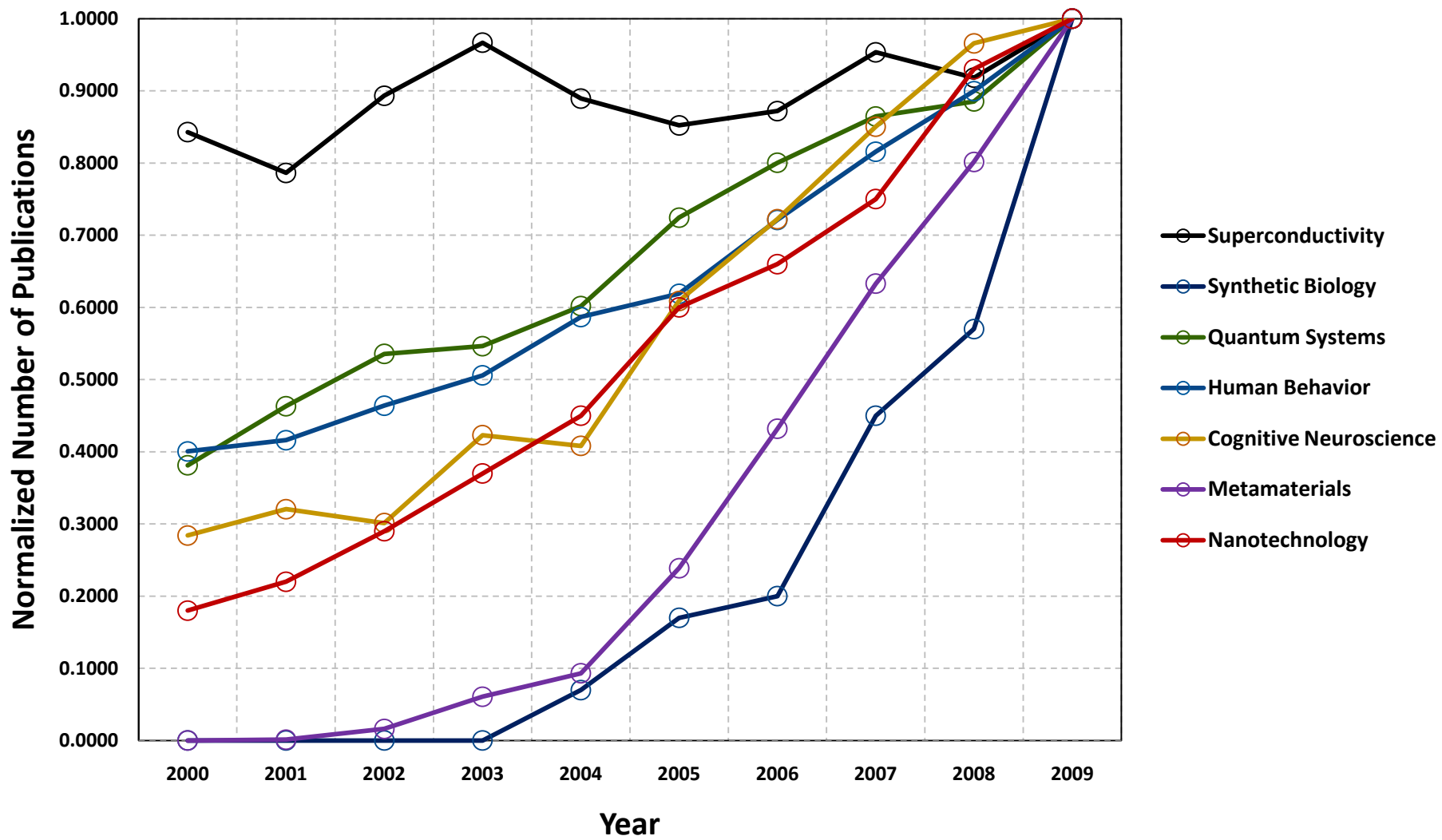
goal-oriented

curiosity-driven
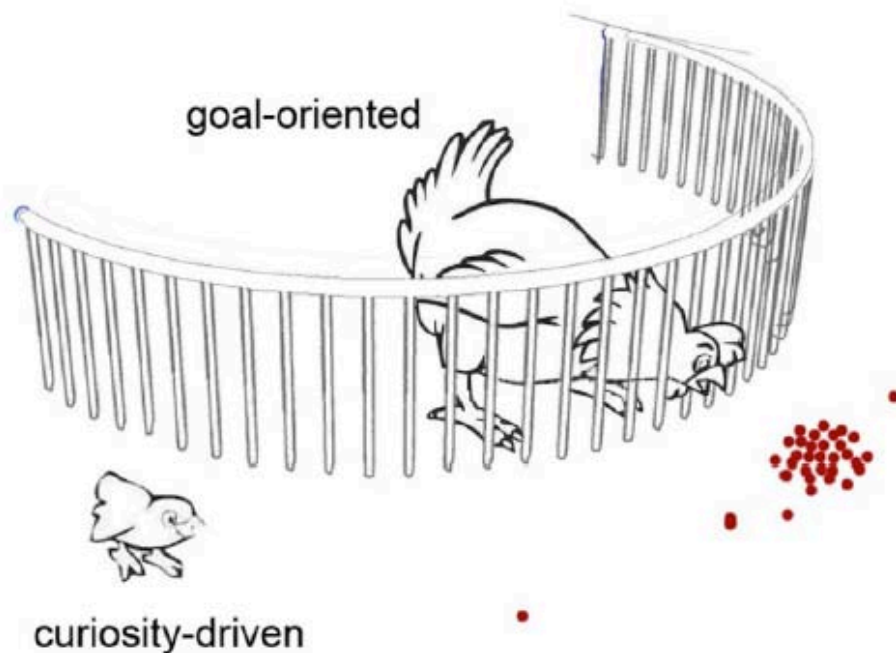
DDRE workshop on Future Directions in Physics, 1/21/2011

**Basic Research should pursue fundamental understanding to provide a foundation for future work**

# Priority Basic Research Areas

# Nanoscience and Nanotechnology

- **Discover and exploit unique phenomena at nanometer dimensions to enable novel applications**

- **Enabled capabilities**
  - Electronics and Sensing: Multispectral focal plane arrays
  - Power and Energy:  Fuel-cells, portable electronics, thermoelectrics
  - Coatings: Photactive, self-cleaning films

- **Select breakthroughs**
  - Nano-particle coating & functionalization
  - Catalysts for energy-harvesting
  - Graphene and carbon nanotubes

- **Key research challenges**
  - Low defect density graphene over large areas
  - Production and reproducibility of chirality nanotubes and bilayers of graphene

# Synthetic Biology/Panomics

- **The promise of engineered biology for a multitude of applications**

- **Enabled capabilities**
  - Bio-production including bio-fuels, food production
  - Bio-sensors
  - Tissue regeneration, broad-source vaccinations
  - 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

# Quantum Information Science

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

- **Enabled capabilities**
  - Quantum computing, Quantum communication
  - Quantum simulation
  - Quantum sensing, metrology and imaging

- **Select breakthroughs**
  - Quantum factorization algorithm
  - Quantum gas microscope

- **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

# Metamaterials and Plasmonics

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

- **Enabled capabilities**
  - Nanoscale subsurface spectroscopy
  - Plasmon-enhanced detectors and imagers, Phased arrays
  - Novel coatings; Microvascular autonomic composites

- **Select breakthroughs**
  - Sub-wavelength elements, plasmonics, photonic crystals, metamaterials
  - Self-sensing and self-healing materials
  - Biologically-inspired structures

- **Key research challenges**
  - Efficiently convert optical radiation into localized energy
  - Enhanced local photophysical processes; 3-D photonic structures
  - Integrated plasmonics with nanostructured semiconductor devices

# 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
  - Ameliorate/prevent PTSD and TBI

- **Select breakthroughs**
  - Advances in brain imaging, e.g., fMRI, Diffusion Tensor Imaging, digital EEG
  - Advances in correlation of brain-structure to function
  - Massively parallel computation enabling brain signal analysis

- **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

# 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
  - Real-time cultural situational awareness; Immersive training

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

- **Key research challenges**
  - Conflicting theories
  - Data management and fusion
  - Mathematical complexity; validation of models

# Summary

- **Future operations capabilities depend on the basic research achievements of today**

- **Five goals for DDR&E to strengthen the defense basic research program:**
  - **Provide scientific leadership** for the DoD basic research enterprise
  - **Attract the Nation's best S&Es** to contribute to and lead DoD research
  - **Ensure the coherence and balance** of the DoD basic research portfolio
  - **Foster connections** between DoD performers and the DoD community
  - **Maximize the discovery potential** of the defense research business environment

- **Achieving these goals results in a coherent, forward-thinking basic research program supported by the Nation's top researchers and paving the way for tomorrow's revolutionary breakthroughs**